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THE

AGRICULTURAL LEDGER.

1898—No. 2.

SOILS.

(INDIAN SOILS.)

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ON THE COMPOSITION OF INDIAN SOILS.

Note by DR. J. W. LEATHER, *Agricultural Chemist to the Government of India.*

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ON THE COMPOSITION OF INDIAN SOILS.

A Note by DR. J. W. LEATHER, *Agricultural Chemist to the Government of India.*

1. The subject of Indian soils was dealt with by Dr. Voelcker in Chapter 5 of his Report, and in that chapter the following matters are discussed:—

Dr. Voelcker's Report. Chapter V. Synopsis of contents.

(*a*) the composition of Indian soils, (*b*) the possible exhaustion of Indian soils, (*c*) the supply of nitrogen to Indian soils by rain and leguminous plants, (*d*) the reclamation of certain lands which have become infected by *kans* grass, eroded by surface drainage, or infertile from the presence of salts of sodium called reh.

Of these four subjects, (*d*) has been dealt with in *The Agricultural Ledger* Nos. 12 and 13 of 1893 and Nos. 7 and 13 of 1897, which deal with Reh and Usar, and No. 16 of 1894 describes certain methods of reclaiming Ravine Lands.

2. Regarding (*c*), the supply of nitrogen (ammonia and nitric acid) in the rainfall, some determinations have been made by Dr. Van Geyzel in Madras, who found in one year 4 lbs and in

Nitrogen in rainfall.

another year 2·1 lbs. nitrogen per acre to be so deposited, and by Mr. Kelway Bamber at Calcutta, who found 3.39 lbs. per acre in the rainfall between May and October. The second part of this subject, namely, the assimilation of nitrogen by certain members of the natural order LEGUMINOSÆ, has been referred to in *Agricultural Ledger* No. 7 of 1894 as well as in many European journals. No work on this subject has been done specially for India; and since it is probable that the part which these plants play in relation to the supply of nitrogen to the soils of India is a very important one, a large field of very useful work remains to future investigators.

Assimilation of atmospheric Nitrogen.

The present paper deals principally with the composition of Indian soils. Most of the information here given has been obtained during my tenure of office as Agricultural Chemist to the Government of India. For one section, however, I am indebted to Mr. Kelway Bamber's book on "The Chemistry and Agriculture of Tea," from which I have extracted the information relating to the composition of the Assam tea garden soils.

The subject of the possible exhaustion of Indian soils finds a place at the end of this note.

3. ***The composition of Indian soils.***—In the opening paragraph of his chapter on soils, Dr Voelcker writes: "The soils of India have not so far been made the subject of careful or scientific study. A few analyses are recorded of the soils of particular spots, and on two of the Government experimental farms a practical analysis of the soil has been attempted by growing crops on them. Such experiments have a certain value it is true, but they fall far short of what may be gained by a systematic and scientific enquiry. Again, in paragraph 419, among the subjects which Dr. Voelcker recommends as suitable for investigation by an Agricultural Chemist, is "the sufficiencies and deficiencies of different soils in respect of the various soil constituents." Finally, in paragraph 424 Dr. Voelcker suggests that the Agricultural Chemist might usefully "assist the spread of agricultural education by the preparation of simple text-books."

Need for a better knowledge of Indian Soils.

It was indeed more with a view to trying to fulfil the latter recommendation than anything else, that I obtained through some of the Local Governments and others samples of typical soils, and have subjected them to chemical analysis. The completion of this work has been delayed through other duties longer than I had at first

anticipated, and the text-book which I had hoped to prepare before the close of the present year will not have been written. The outcome of the work is, nevertheless, a fairly accurate knowledge of the composition of certain types of Indian soils; and considering the almost total absence of any information on the subject and the need there is for it as an aid to agricultural teaching in the several agricultural colleges and schools, the matter contained in the present note will, I doubt not, prove itself of assistance to lecturers.

Besides exhibiting the general composition of the certain classes of soils to be referred to, I have been able, I believe, to explain satisfactorily the cause of the colour of the "black cotton soil" (*regur*), which has been the subject of some little speculation.

4. ***Types of Soils.***—As pointed out in paragraph 45 of **Dr. Voelcker's** Report, the number of main types of soils in India is far smaller, and their position geographically far more readily defined, than is the case with those in England; and although the variations are greater than is suggested by a mere glance at the Geological map of India, it is nevertheless true that one may divide the principal soils of this vast peninsula, which approaches the area of Europe, under about four chief heads, the soils of which are each so perfectly distinct in colour and texture from one another, and stretch uninterruptedly over such very large areas, that such a classification is not only admissible, but essential. It is not, indeed, a matter of distinguishing clays from loams and sandy soils or marls, for each of the principal Indian types of soils includes those which are more clayey and those which contain much sand or gravel, but one rather of distinguishing soils which cannot be confused the one for the other.

Principal Types of Indian Soils.

The four main types of soil to be dealt with, and which certainly occupy by far the greater part of the Indian cultivated area, are the Indo-Gangetic and other alluvium, the black cotton soil or *regur*, the red soils lying on the metamorphic rocks of Madras and the laterite soils which are met with in many parts of India. There are doubtless other minor classes of soils, but they neither possess such characteristic differences in appearance, nor are they distributed over such extensive areas as the four types referred to. For instance, stretches of alluvium have been formed at the mouths of the Rivers Mahanadi, Godaveri, and others, but the area of these deltas bears no

Minor classes of Soils.

comparison to the Indo-Gangetic alluvium. Again, I found the soil covering the Dharwar system in the Dharwar District quite different from the *red* soils of the metamorphic rocks in the Madras Presidency.

Probably a more exhaustive study of these various smaller classes of soil might be worth while undertaking. My first aim was, however, to be able to form an idea of the general constitution of the four classes named, to determine in what essential respects they differ from one another, and whether any of them may be said to be usually rich in plant food.

Other soils referred to.

5. In addition to an examination of these main types of soils, analyses of several other descriptions of soil have been undertaken. Ten soils of brown coloured alluvium, principally from the valley of the Cauvery, have been analysed. Six soils from a coffee estate in the Sheveroys have also been examined.

Assam Soils.

From Mr. Bamber's Book on "The Chemistry and Agriculture of Tea" I have extracted much valuable information regarding the composition of the Assam Tea Garden soils.

From these Investigations it is possible to set out fairly exactly what are the chief characteristics of Indian soils generally. Several reports on the composition of soils, which constituted enquiries of a special nature, also find a place in this Note.

The soils of the Indo-Gangetic alluvium.

Physical Characters.

6. It is unnecessary to define to what area the Indo-Gangetic alluvium belongs, or to say that, from Karachi on the West to Bengal on the East, one may pass without finding a single pebble ; the only rocky particles larger than sand which this great expanse of land contains, is the nodular limestone which has been called "*kankar*", and which has formed by the deposition of calcium carbonate in the soil within a few feet of the surface. This large expanse of land consists generally of a yellow coloured alluvium, sometimes sandy, sometimes becoming a stiff clay, and the latter is also more of a blue-grey in places. Occasionally, too, sand *duns* or hills have been formed by the wind.

A number of soils which are fairly representative of this alluvial area have been analysed, and these analyses are exhibited in the accompanying Statement No. 1.

Sandy soil.—Among these soils only one (No. 20—93) is a really sandy soil. It was taken from a well cultivated field of what has been called the Ison Sand Belt in the Cawnpur District.

Sandy loams.—Two samples are of sandy loams: The one, No 22—93, is from a very fertile tract lying between the Ison and Ganges, also in the Cawnpur District; the other, No. 339-94, is a sample of the soil of the Burdwan Experimental Farm, and may likewise be considered a typical sandy loam.

Loams.—The majority of the samples analysed are loams. The first, No. 15—93, is from the Cawnpur District, Nos. 386 & 387—95 are from the Changa Manga Fuel Plantation in the Punjab, No. 33—95 is the surface soil of the new farm at Dumraon, No. 302—96 is the mean of the analyses of two loams from the Bahr Subdivision of the Patna District.

Clays.—The three following samples were more or less clayey soils, though none of them could be considered a stiff clay. No. 41—95 is the sub-soil of the Dumraon (new) farm, No. 299—96 is a clayey soil from the Bahr Sub-division of the Patna District, No. 17—96 is a sample of the soil (surface) from the Sibpur Farm.

Calcareous soil.—Lastly, No. 127—93 is a calcareous soil from Captain Chapman's estate in the Partabgarh District of Oudh. Calcareous soils occur very rarely.

Beds of *kankar* commonly underlie both the alluvium and the *regur;* perhaps similarly other soils. In the case of the alluvium, this *kankar* is only found mixed with the surface soil when the bed of *kankar* is very near the surface. Otherwise the surface soil of the alluvium is remarkably free from this material. In the black cotton soil (*regur*) *kankar* frequently lies in beds a few feet under the surface, but, *in addition*, small pieces of the same material are found intermixed throughout the soil, and in some of these soils the amount of calcium carbonate approaches 10 per cent. **Kankar.**

7. Excepting in the case of the soil from Captain Chapman's estate, the largest amount of carbonic acid in any of the alluvial soils examined was 1·35 per cent. Assuming this to be entirely combined with lime, it corresponds to 3·06 per cent. calcium carbonate. The land on Captain Chapman's estate, from which the calcareous sample was taken, is a low-lying area which, until recently, was annually inundated by the river Ganges, and the large amount of lime is doubtless due to the agency of shell-fish. **Lime in Captain Chapman's soil.**

Of these alluvial soils generally, it may be noted that the amount

Equally more Phosphoric acid in these soils than in other types.

of phosphoric acid, though not large, is frequently more than other classes of Indian soil usually contain.

Nitrogen and organic matter.

The amount of nitrogen and organic matter varies within much about the same limits as in those examples quoted by Dr. Voelcker (paragraph 58). They are low excepting in two cases, the one being the surface soil of the Changa Manga Fuel Reserve, the other the calcareous soil from the reclaimed land at Captain Chapman's estate, and both these have been placed under conditions which are particularly favourable to an accumulation of organic matter and nitrogen.

Comparison with European Soils.

In other respects these soils are similar in composition to European loams and clays. The amount of iron and alumina is perhaps somewhat higher, but the divergence is not great. The sandy soil No. 20 contains 2½ per cent. of each, and in the others the proportion rises, until in the clays it amounts to 6 or 8 per cent. of each. The proportion of magnesia, which varies from ½ per cent. in the more sandy soils to 1½ per cent. in the clays, is perhaps somewhat higher than in English soils generally. It is to be noted that, whilst sulphates are generally absent from the *regur*, the red soils of Madras and the laterite soils, these alluvial soils frequently contain a small amount.

Potash.

The amount of potash in those samples in which it was separately determined, varied from ·16 to ·66, which must be considered at least ample if not large.

Composition of soils of the Indo-Gangetic alluvium.

	SANDY SOIL.	SANDY LOAMS.			LOAMY SOILS.				CLAY SOILS.			CALCAREOUS SOIL.
					CHANOA MANGA PLANTATION.							
	Ison Sand Belt, Cawnpur District.	Ison Ganges, Doab.	Burdwan Experimental Farm.	Cawnpur District.	Compartment Surface soil 1"—3".	No. 1 Sub-soil. 3"—15".	Dumraon Farm surface soil.	Bahr Patna District.	Dumraon Farm sub-soil.	Bahr Patna District.	Sibpur, Calcutta.	Partabgarh, Oudh.
	20—93.	22—93.	339—94.	15—93.	386—95.	387—95	33—95.	302—96.	41—95.	299—96.	17—96.	127—93.
Insoluble silicates and sand	91·72	88·08	84·31	84·84	77·03	86·06	86·82	82·96	80·90	72·64	73·58	57·52
Iron ($Fe_2 O_3$)	2·36	3·10	5·58	4·52	5·74	4·48	4·09	4·59	6·12	7·58	6·36	3·23
Alumina ($Al_2 O_3$)	2·92	4·38	6·09	5·30	4·36	4·36	4·57	5·11	6·50	9·89	7·93	3·39
Manganese ($Mn O$)	...	...	·12	...	·11	·11	·10	·11	·14	·14	·11	...
Lime ($Ca O$)	·35	·47	·28	·91	·93	1·03	·30	1·78	2·07	1·01	1·52	14·54
Magnesia ($Mg O$)	·78	·38	·66	·52	1·97	1·48	·76	1·53	1·17	1·64	1·61	1·80
Potash ($K_2 O$)	·33	·64	·56	·16	·57	·76	·48	·66	·73	·82	·64	·44
Soda ($Na_2 O$)	·08	·09		·03	·25			·30				·08
Phosphoric acid ($P_2 O_5$)	·08	·08	·04	·10	·19	·9	·08	·13	·08	·07	·11	·18
Sulphuric acid ($S O_3$)	·04	·05	·02	*Nil*	*Nil*	·03	*Nil*	*Nil*	*Nil*	*Nil*	·03	·08
Carbonic acid ($C O_2$)	·27	·37	·21	·71	·43	·47	·01	1·10	·05	·28	1·35	11·48
Organic matter and combined water (difference)	1·07	2·42	2·13	2·91	8·42	1·13	2·79	1·73	2·24	5·93	6·76	7·32
TOTAL	100·00	100·00	100·00	100.00	100·00	100·00	100·00	100·00	100·00	100·00	100 00	100·00
Nitrogen	·028	·081	·042	·046	·237	·043	·049	1·045	·041	·051	·065	·180

Brown alluvial soils from Madras.

Source.

8. A number of samples of brown or greyish alluvial soils have been received from the Madras Presidency, principally from the valley of the Cauvery, and whilst they differ a good deal in colour and texture, still they may be conveniently placed in one class and described together. They are essentially different from the *regur*, the red soils and laterites, and from the alluvium of the Indo-Gangetic Plains. They appear to be free from pebbles, and although the proportion of iron and alumina is high in the loamy ones, not one of them could be considered clayey.

Description of samples.

The Statement No. II. exhibits their composition, and the following are the descriptions which were sent with them.

No. 374—96. "Brown alluvium of great depth from the bed of a ruined tank. Cholum grows nearly 20 feet high on this soil, and the stalks are chiefly used for fuel; the grain produced is more bitter than that produced elsewhere; *kariali* grass (Cynodon Dactylon) grown on this soil is also bitter and fetches a low price in the market."

No. 375—96. "Black loam; lies on a gravelly substratum at a depth of 2 or 3 feet; is therefore unfit for cocoa-nuts. The ryots complain that the soil of this and the neighbouring fields is not retentive enough, and needs to be more frequently watered than the fields further down the Cauvery Valley. Irrigated under the Kaling-arayan channel from the Bhavani."

No. 377—96. "Clay, black; more mellow and clayey than No. 375. At a depth of 3 to 5 feet there is a bed of impalpable black sand; cocoa-nuts and plantains thrive on this remarkably, and nowhere in the Cauvery valley are cocoa-nuts more extensively cultivated. The nuts are comparatively small." (The sample received could not be called either black or clayey; it consisted of a dark brown loamy soil.)

No. 331—96. "Red loam; this is the kind called *yerra masaka* in the Ceded Districts; locally called *Sempidippu karambai*." The sample received consisted of a peculiarly soft dark *brown* soil, inclined to adhere in soft lumps. It will be noted that No. 75—96 (*vide* black soils) is also called *yerra masaka*, but the two are absolutely different in appearance and nature.

No. 381—96. "Loam, pale on the surface, but black below. Though entered in the Settlement Register as black clay, it is fairly

friable, called in Tamil *palpottai*, produces good crops of ground-nuts, overlies a calcareous stratum at a depth of more than 5 feet.

Description of samples.

No. 384—96. "Loam; retains its natural red colour; as thin as No. 383, taken up for cultivation only a few years ago; less fertile than No. 383."

No. 382—96. "Sandy soil with fine particles; black; uniformly friable to a great depth, has been cropped with *kambu* (Pennisetum typhoideum) every year mixed with ground-nuts in alternate years, *gingelly* following *kambu* in other years; fertile."

No. 383—96. "Loam; natural colour red; but now turned grey having been manured liberally with ashes and canal silt; overlies a bed of sandstone at a depth of 12 to 18 inches; has been cropped with groundnuts almost every year for more than 20 years."

No. 385—96. "Sandy; red soil from the right bank of the Gaddilam river near Panruti; has now turned grey having been plentifully manured with ashes and tank silt; cropped incessantly with ground-nuts and *kambu* for many years; is more than 20 feet deep and is red throughout, except near the surface."

No. 386—96. "Loam; light coloured; has turned grey having been manured plentifully with ashes and tank silt; the soil consists of fine particles and is uniformly friable to a great depth. Has been cultivated with ground-nuts with occasional change of crops for more than 30 years."

Nos. 383 and 386, although described as loams, should be classed as sandy soils.

Iron and Alumina high.

9. Of these ten soils, all the loamy ones contained high, some of them very high, proportions of iron and alumina. The amount of lime is small excepting in one case, and in no case is there much carbonate of lime. The amount of magnesia is high in five of the samples. The proportion of potash, in those samples in which it was determined, is fairly high, and in no case deficient.

Potash.

Phosphoric and Nitrogen.

Of phosphoric acid the amount is in no case large, and is in much the same proportion as occurs in the other descriptions of soil from Madras. The amount of nitrogen is as small as in most other classes of Indian soils. The amount of volatile matter is high in some cases, but this occurs principally in those soils which contain high proportions of iron and alumina, and is doubtless due to loss of combined water.

Judging by the descriptions they are very fertile soils, but it would appear that they are regularly manured.

STATEMENT No. II.

Composition of brown alluvial soils from Madras Presidency.

	LOAMS.						SANDY SOILS.			
	BELLARY DISTRICT.	COIMBATORE DISTRICT.	TRICHINOPOLY DISTRICT.		SOUTH ARCOT DISTRICT.		SOUTH ARCOT DISTRICT.			
	Hospet Taluk.	Erode Taluk.	Kalitalai Taluk.	Perambalur Taluk.	Chidambaram Taluk.	Cuddalore Taluk.	Cuddalore Taluk.			Villupuram Taluk.
	374—96.	375—96.	377—96.	331—96.	381—96.	384—96.	382—96.	383—96.	385—96.	386—96.
Insoluble silicates and sand	57·62	78·46	75·79	66·03	82·33	77·09	95·04	87·61	96·01	93·71
Iron (Fe_2O_3)	17·30	4·84	7·12	10·33	4·84	8·27	2·05	3·46	1·65	3·68
Alumina (Al_2O_3)	10·23	7·97	7·86	15·28	5·85	10·60	1·06	3·89	·90	1·12
Manganese (MnO)	·26	·07	·07	·20	·09	·05	·04	·06	·03	·04
Lime (CaO)	·58	·38	·44	1·23	·32	·05	·15	·10	·09	·18
Magnesia (MgO)	1·82	1·23	1·54	1·87	1·04	·21	·51	·26	·20	·33
Potash (K_2O)	·27	·43	·19	·28	·98	·10	·03	·11	·07	·09
Soda (Na_2O)	·38	2·42		·07		·06		·16		
Phosphoric acid (P_2O_5)	·10	·09	·14	·08	·06	·14	·03	·10	·04	·04
Sulphuric acid (SO_3)	...	...	...	...	...	...	...	...	...	...
Carbonic acid (CO_2)	·16	·03	·03	·08	·06	·09	·13	·09	·14	·09
Organic matter and combined water	11·98	4·08	6·82	4·55	4·43	3·34	·96	4·16	·87	1·72
TOTAL	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00
Nitrogen	·091	·105	·057	·046	·017	·008	·010	·009	·003	0·19

REGUR or "BLACK COTTON" SOILS.

Description of Samples.

10. With two exceptions the soils referred to in the accompanying Statement are all true *regur* of *good* quality; the soil from Coimbatore, No. 292—94, and No. 114—95, from Anantapur, are a *bit gravelly*. The following are the descriptions which accompanied the samples.

No. 380—96. "Black loam; one of the four classes of black cotton soil recognised in Madura and Tinnevelly. It is called *Veppal*. The characteristics are a pale white colour of the surface and such an open texture that it is not fairly retentive. Is several feet deep and rests on *kankar*."

This is a sample of good *regur* and contains small bits of white *kankar*. It is not clear how the land can have a white colour.

No. 329—96. Madura District, Terumanyalum Taluk. "Black clay; though there had been no rain for a long time, there was moisture 9 inches below the surface."

No. 330—96. Madura District, Terumanyalum Taluk, "Black clay; this is the same as what is called *Choudu regada* in the Ceded Districts, but not quite so hard."

No. 332—96. Trichinopoly District, Perambalur Taluk. "The soil is a black loam not injured by heavy rainfall." (Although this soil is described as a loam, it has all the characteristic appearances of a good "*regur*", and the analysis shows that its composition coincides with the other "*regurs*". The proportion of iron and alumina, though somewhat high, is not exceptional, and the amount of lime normal, as is likewise the nitrogen and organic matter; the proportion of phosphoric acid is very small. I have therefore placed it among the good *regur* soils.

No. 292—94. Coimbatore District, Coimbatore. This soil is a true *regur*, but somewhat less coherent than most.

No. 114—95. Anantapur District. This is described as "Rather inferior black soil". It is also somewhat gravelly and less coherent than most.

No. 248—96. Anantapur District, Gooty Taluk, "*Regur* clay; Nalla Regadi or pure black cotton soil."

No. 72—96. Kistna District, Guntur Taluk. "*Regur* clay (*Banka regada*); known locally as *Kullu regada*, literally rotting regada. It is so retentive of moisture, that crops thrive on it only in years of moderate or deficient rainfall; contains small pieces of limestone

Descriptions of Samples.

called in Telugu 'Guvarayi'. The larger the proportion of the limestone, the worse the soil is held to be."

No. 73—96. Kistna District, Guntur Taluk. *Regur* clay (*Banka regada*); called locally *Pulludu regada*, literally sour regada. Requires more rain for the successful cultivation of crops than "*Kallu regada*". Contains a larger proportion of "*Guvarayi*". (As a matter of fact the sample received did not contain a larger amount of "*Guvarayi*" limestone, but just about as much as No. 72, to which this comparative remark has reference.)

No. 76—96. Krishna District, Sattenapalle Taluk. "*Regur* clay; the soil is remarkably hard, does not crack in summer so much as the ordinary black cotton soil. Does not easily get softened by immersion in water. Agricultural implements are worn out comparatively soon Indigo leaf, produced from this sort of soil, gives as a rule a larger proportion of dye than that produced elsewhere. Requires plenty of rain for the successful cultivation of crops "

(So far as the eye could tell, this soil was a good *regur* of normal quality, and contained but little *kankar* limestone; the analysis is also quite normal.)

No. 77—96. Kistna District, Narsaraopet Taluk. "*Regur* clay; *Krishna regada*."

No. 78—96. Kistna District, Narsaraopet Taluk. "*Regur* clay; *Pulludu regada*. There is scarcely any *guvarayi*."

No. 80—96. Kurnool District, Cumbum Taluk. "*Regur* clay; locally called *Nalla or Krishna regada*."

No. 247—96. Kurnool District, Ramallakot Taluk. "*Regur* clay; cracks much in the dry weather; known as *Accha regadi* or pure black cotton soil."

No. 249—96. Kurnool District, Pattikonda Taluk. "*Regur* clay; a clay soil called locally *Marabhumi*, very hard but retentive of moisture; fertile."

No. 252—96. Cuddapah District, Pulivendla Taluk. "*Regur* clay; called locally *Banka regadi* (that is black clay soil); the cracks were wide and deep."

Nos. 276—96 and 277—96. Nagpur. This is the soil of a plot at the Experimental Farm which has not been manured for a long period of years. A crop of wheat (averaging some 600lbs. of grain per acre) has been taken off it for 12 years.

Comparison of Vernacular names.

11. It will have been observed that in several instances the same vernacular name is applied to two or more of the samples. For example, Nos. 73 and 78—96 from the Kistna District are both called *palludu regada;* No. 73 is said to contain "a larger proportion of *gavaraya* (*kankar*) than Kullu regada", whilst No. 78 is said to contain "scarcely any *gavaraya*". In appearance the samples were notably different from one another. The analysis shows that No. 73 contains scarcely any calcium carbonate; No. 78 contains a fairly high proportion. No 72—96 is described as "*banka regada*, known locally as *kullu regada*; No. 73 is called *banka regada*, known locally as *palludu regada*. The former is said to be "so retentive of moisture, that crops thrive on it only in years of moderate or deficient rainfall", whilst No. 73 is said to require "more rain for the successful cultivation of crops than *kullu regada*."

One might have expected some difference in the composition of these two soils, such as less iron and alumina or more *kankar* in No. 73, but such is not the case; the composition of the two is as nearly alike as possible.

No. 252—96 is also called "*banka regadi*", but this soil has a composition widely divergent from Nos. 72 and 73.

No. 77—96 is described as "*krishna regada*", No. 80—96 as "*Nalia* or *Krishna regada*", and No. 248—96 as "*nalla regadi*". In composition No. 248 is similar (except in the amount of alkalis) to No. 77, but No. 80 differs considerably from them in several respects.

Thus it would seem that these terms are not related at all to the chemical composition of the soils. Doubtless to the people they have a comparative significance, but if this be so, it is probable that they are related to certain phygical peculiarities dependent as much on the nature of the subsoil or drainage as upon anything else.

Uniformity of composition of Soils.

12. If the analyses of these 18 *regur* soils be examined, it will be seen that there is comparatively but little variation in their composition. In fact, it is remarkable how uniform their composition is. The individual constituents may with advantage be examined.

Insoluble silicates and sand.—One sample contained only 56 per cent., and two others with appreciably less than 65 per cent.; there is only one which contained more than 75 per cent.; 14 samples contained proportions lying between 65 and 75 per cent. Silicates low.

Iron high.

Oxide of iron.—The majority of the samples contained from about 5½ to 8½ per cent. One sample contained only 4·3; the Nagpur sample contained over 11 per cent., and the one from Trichinopoly District 9·2, but these appear to be extreme limits.

Alumina high.

Alumina.—The greater number of the samples contained from 8·5 to 11 per cent., of alumina. Two samples had only 6·3 and 6·8 respectively, whilst in four others there was 11·8, 12·0, 12·7 and 13·7 per cent., the extreme variation being about the same as in the case of iron. In all the Madras samples there was more alumina than iron by about 1 or 2 per cent. In the Nagpur sample the reverse is the case.

Manganese.—The amount of this constituent is very constant, the lowest amount found being ·09, the highest ·26. In two cases the amount is less than ·12, and in one case it was ·26, but all the other samples contained amounts varying from ·12 to ·25 per cent. of manganese. In the statement of analysis the manganese is entered as manganous oxide. It may be that some part of the manganese exists as dioxide, which I have at least once found in an Indian soil, but the amount of dioxide is certainly not great, and in the presence of organic matters such small quantities are difficult or impossible to detect.

Amount of lime varies.

Lime.—The proportion of lime varies in the samples considerably not only in its total amount, but also in the condition in which it exists.

With one exception it exists in part as carbonate and in part as silicate. In those samples in which there is 2 per cent. or more CaO, the greater part is carbonate; where, however, the total amount of lime is less than about 2 per cent., the greater part exists as silicate. They generally contain from 2 up to 4 or 5 per cent.

Magnesia high.

Magnesia.—The amount of magnesia is high in all samples, and varies from 1·3 to as much as 3·1 per cent. In two samples there is appreciably less than 2 per cent., and three in which it is more than 2½ per cent., namely, 2·6, 2·7 and 3·0; in the remainder of the samples the variation falls between the limits of 2 to 2½ per cent.

Alkalis vary.

Alkalis.—The alkalis vary very considerably, the lowest proportion being ·15 per cent., the highest 2·44 per cent. The amount is, however, in the majority of samples unusually large. In those samples in which the potash was separately determined, it was present

in ample amount for all agricultural purposes and above what is generally found.

Phosphoric acid.—The amount of this valuable plant food is small in nearly all cases. One sample contained ·19 and another ·23 per cent., but in all the remainder the proportion fell below ·1 per cent., and in many cases much below this figure. **Phosphoric low.**

Carbonic acid.—The carbonic acid exists in combination with the lime, and varies to a greater extent even than does that constituent. Apparently the carbonate of lime agglomerates together not only as *beds* of *kankar*, but also as quite small lumps of this material. At any rate many of these soils contain small round bits of *kankar* about the size of mustard seed. **Kankar commonly present.**

Sulphuric acid.—Most of the samples contained no sulphates, and in no case was the amount anything appreciable. **Generally no Sulphates.**

Nitrogen.—The amount of nitrogen is very small, as is common to Indian soils generally. The smallest amount is ·012 per cent., the highest ·050 per cent. **Little Nitrogen.**

13. ***Organic matter and combined water.***—The loss in weight which soils experience when heated moderately is occasioned by the combustion of the organic substances, the expulsion of water chemically united with the minerals of the soil, and possibly a little carbonic acid from the calcium carbonate; this latter, however, does not form any material part of the loss. It would of course be interesting to know the amount of organic carbon present apart from the "combined water", but this had to be left undone. A conclusion may nevertheless be drawn concerning its amount. The proportion of "organic matter and combined water" is higher than in most Indian soils. **Loss of weight when burnt.**

Among the soils representing the Indo-Gangetic Alluvium, one from Changa Manga contained 8·42, and the calcareous soil from Partabgarh 7·32 per cent., but in these the loss was principally due to *organic matter*. Two of the clays suffered about 6 per cent. of loss on heating, which was probably mainly due to combined water. Among the laterite soils, Nos. 284, 285 and 358 suffered considerable loss on heating, principally owing to the presence of large amounts of *limonite* which gives up its one molecule of water when heated. **Other classes usually lost less than *Regur*.**

Among the *red soils* from Madras one sample suffered a loss of 7·4 per cent., due principally to combined water. Generally, however, these three types of soils suffered very considerably less loss on heating than did the *regur* soils.

Loss of weight of Regur usually high, but not due to organic matter.

On the other hand, when these latter are heated, the loss is almost uniformly high, but there are no indications of any particularly large amount of organic matter. They simply change colour from black to a dark brown. If a soil contain any notable quantity of humus, its combustion can be unmistakably observed.

Reasons.

The proportion of nitrogen is as low in most of these *regur* soils as in other soils which lose only ½ or ⅓ as much when heated. Thus the nitrogen indicates a low proportion of organic matter.

Thirdly the manner in which these *regur* soils contract on drying indicates a high proportion of hydrated ferric oxide or alumina, and either of these compounds would lose the water of "hydration" on being heated. The amount of combined water then must be necessarily much higher in these soils than in ordinary ones. A further point may be referred to, namely, that soils, whether in India or elsewhere, which contain a high proportion of organic matter, possess a peculiarly dark brown appearance, approaching black, but nevertheless quite different from the colour of *regur*. Thus it appears certain that the greater part of the loss which these *regur* soils experience when heated is due to expulsion of combined water, and that there is as little organic matter in them as in most other descriptions of Indian soils.

Fertility of Regur.

14. Reference may also be suitably made in this place to the question of the fertility of *regur*. At page 412 of the *Geology of India* it is stated that "the fertility of this soil is so great that some of the black soil plains are said to have produced crops for 2,000 years without manure, without having been left fallow, and without irrigation." As to the period named, I do not suppose that Mr. Oldham, when reproducing this statement, assumed there was sufficient evidence to prove that the history of any field is so accurately known that its agricultural treatment can be traced for even as many hundreds of years. But still there is a general belief that these soils are immensely fertile. As to the origin of such a belief, it seems to me that it is due possibly to the fact that the *regur* is usually a more fertile soil than those others which frequently adjoin it, such as the

red soils, which are certainly in many cases light gravelly soils, with rock not far from the surface. The power which *regur* has of retaining moisture is so great, that on this account alone it possesses an advantage over these gravelly red and brown soils situated within the same region as the *regur*.

Effect of the fissures.

Then again one of the results of the strongly contracting power of *regur* is not only that it forms deep and wide fissures in the land, but also the surface literally crumbles to a coarse powder, and a part of this is annually carried by the agricultural implements, the *bakhar* for example, into the fissures, and consequently there is constantly going on *an inversion* of the soil, and what has been subsoil comes to the surface.

These two properties must naturally assist in helping the soil to produce crops. But so far from it being the case that *regur* is inordinately rich, it has been pointed out that, in the matter of phosphoric acid and nitrogen, it is very poor indeed, and if other Indian soils are as poor or even poorer in these particulars than *regur*, one cannot for a moment call it a soil of inexhaustible fertility.

Experience at Nagpur.

The outturn of crops too at the Nagpur Farm on unmanured land is lower than on similar unmanured land of the Gangetic alluvium.

Other published analyses of Regur.

15. In the *Geology of India* (2nd edition), page 411, several analyses of black soils are given. The one made by Dr. Macleod (if even approximately correct) is of a soil very different not only to the samples which I have examined, but also to those the analyses of which are published in the same place. The seven other analyses by Mr. Tween are in some respects in fairly close agreement with mine. The undried soil was employed, and, if the mechanically contained water (7 to 10 per cent.) be withdrawn from the analyses and the remaining items calculated for 100 per cent., the figures would become comparable with mine. The silica varies between the same limits as it did in my samples. The iron and alumina *taken together* are also present in similar amount; but whilst in most of the samples which I analysed there was rather more alumina than iron, in Mr. Tween's analyses there is more iron than alumina in the soils from Seoni and Indore, the other two containing reverse proportions. The proportion of calcium carbonate too is similar. Mr. Tween left magnesia, alkalis, and phosphoric acid undetermined. The amount entered as "organic matter" must have been determined by heating

the soil, since there is no other method available, and thus the combined water is included; this item also agrees with what I found.

Assumed high proportion of organic matters.

I have thought it desirable to go into these analyses somewhat in detail, because on their evidence it has been assumed that "there appears always to be a considerable quantity of organic matter combined. The black colour appears to be due either to the carbonaceous elements of the soil or to organic salts of iron". As to there being any inordinate amount of *organic* matter in black soil, I have already shown that there is no evidence in *support* of such a conclusion, but rather much which is antagonistic to it. The second of the above assumptions, namely, that the colour is due to the presence of "organic salts of iron", is one difficult to discuss. It was once suggested to me that the black colour of *regur* was due to the presence of some plant which produced a dye from the root! Such a plant has never, so far as I am aware, been found anywhere. Supposing, however, that such had happened, it is true that a quantity, so small as not to materially increase the proportion of "organic matter", *might* have produced the result. But not only is this a mere assumption, there is, in addition, much evidence of a conflicting nature.

Salts of iron.

Suggested presence of organic dye.

Peculiarities of *Regur*.

It is well to bear in mind that these *regur* soils have two peculiarities: the one being the colour, slaty-black to very dark brown-black, the other, the unusual degree to which they contract on drying. The colour of the land frequently varies more or less; sometimes it appears quite *grey*, but this is obviously produced by the presence of *kankar;* sometimes it appears *brown* on the sides of cuttings. But I am convinced that there *is* some constant ingredient of these soils which *is* either black or slaty-black. It *may* be that the black coloured ingredient and the ingredient which causes the strong contraction on drying are identical; it is much more probable that they are *not*. Now, referring to the possible presence of "organic salts of iron", it must be remembered that at the high temperature (often 50°—60° C. or 120°—140° F.) to which the surface soil is subjected in India during long months each year, oxidation *must* be rapid, and doubtless is so, and one cannot imagine any organic salt of iron remaining unoxidised for generations under such circumstances.

Organic salts of iron can hardly be present

Again, supposing some particular plant were constantly producing a dark coloured material, how comes it to do so only in *the* soil which contracts so peculiarly? Our knowledge of plants is that they

do *not* exclusively grow on some particular soil. Thus it is difficult to conceive that the colour is due to organic matter at all.

At page 414 of the *Geology of India* reference is made to Mr. Blanford's paper (*Memoirs IV.*) in which he states that he found *regur* being formed in lagoons by the sea. In a foot-note at page 135 of *Memoirs IV.* (2) Dr. King states that the "*regur*" described by Blanford was not true *regur*.

Geologists' opinion as to formation of *Regur*.

Again, in the same paragraph of the *Geology of India*, reference is made to Mr. Blanford's paper (*Records VIII.*), in which he points out the similarity between the mud at the mouth of the Tapti and the *regur* of the neighbouring country, and for geological reasons assumes that the former is now being formed, and that the latter was originally formed *by the sea*. I have also seen the same country, and I must say that it appeared to me that the black mud at Surat was simply the silt brought down by the Tapti from the neighbouring *true regur*. The flow of the river is stopped at Surat by the tide, and the mud has an opportunity to deposit itself.

Tapti mud.

Messrs. King and Foote concluded that *regur* was formed in marshes; that the now high lying *regur* was originally submerged. Here again this seems to be a conclusion not warranted by facts. It is true that the mud of marshes in Europe or *jhils* in India is usually dark coloured, a colour due in many cases to organic matter and sometimes to ferrous oxide, or again to the clay being itself grey coloured, but unless due to ferrous iron, the organic matter of marshy land produces a soil of a much lighter brown colour than any true *regur*; the presence of free ferrous oxide is quite out of the question; and lastly the clayey deposits usually formed in *jhils* never has the same black colour nor the extremely high contraction which *regur* possesses.

Mud of marshes and *jhils*.

16. In my opinion one *must* come to the conclusion that the colour of *regur* is *not* due to organic matter. It is much more probable that *regur* has been formed from some particular rock which, on decomposition, forms not only a highly argillaceous soil, but also during disintegration liberates a black or very dark coloured *mineral*. Many geologists have contended that *regur* is the product of the decomposition of trap rocks. Oldham (page 413, *Geology of India*) says this view cannot be maintained because (1) "basalt generally decomposes into a reddish soil quite different from *regur* in character,"

Colour of *Regur* not due to organic matter.

Several products of Basalt.

(2) he considers that Hislop's view, that the colour of *regur* is due to impregnation of organic matter, is the most probable theory. One must of course admit that basalt *is* decomposing, at least in places, into a red soil, and what is still more puzzling is the fact that, while one finds this the case on the steep slopes of the hill-sides, it is just as common to find that *immediately* at the foot of these same slopes comes the true *regur*. Another point may advisedly be borne in mind, namely, it appears to be admitted that *some* of the *laterite* has been formed from trap. It is clear that *some* trap is decomposing into a red soil entirely different from laterite, and consequently if trap can produce two soils so different as these, why should not some descriptions of trap prodnce the *regur*.

17. I have referred to this subject somewhat at length principally because I believe there is *no* reason for assuming the colour of *regur* to be due to organic matter; that on the contrary there is every reason for assuming such to be impossible. Not only is the amount of organic matter in *regur* always small, but in no soils from the *plains* of India *which have been regularly exposed to the sun's influence for a considerable time* have I found even what is in Europe generally considered an ordinary amount of humus.

Indian soils usually cont. in little organic matter

One soil from Oudh, which until recently was annually submerged by the Ganges, and which has now been reclaimed, contained probably a considerable amount of organic matter; the surface soil *from the Changa Manga plantation naturally also contained a good deal* of humus, but these are cases of soils having been regularly placed under protective circumstances. Again, the coffee soils from the Sheveroy Hills contained likewise high proportions of the same material, but the temperature in that situation is much below what is common to the plains, and the land is regularly manured and also protected by the shade of the bushes.

Exceptions.

And if the colour of *regur* is not due to organic matter, it *must* be due to the presence of some *mineral* substance. As a matter of fact *regur* does contain a dark coloured mineral which I have reason to believe *is* peculiar to this soil. If *regur* be *boiled* with concentrated sulphuric acid for several hours, the insoluble residue is very dark brown. I noticed this peculiarity during the process of determining the nitrogen (the first step of which consists in boiling the soil with concentrated sulphuric acid). I have had portions of a number of

Regur contains dark coloured mineral.

the Indian soils treated in this manner, specially to note the colour of the silicates insoluble in sulphuric acid, and the following are the notes I made. All were treated in precisely the same way, namely, 10 grammes of the soil was simply boiled with concentrated sulphuric acid for several hours. After cooling water was added and the sand washed by decantation. The colour of the latter was then noted. In the case of Nos. 329, 330, 332, 292, 248, 72, 73, 77, 78, and 249, all good *regur* soils, the silicates were almost entirely very dark brown or black coloured, and white silicates could only be seen with difficulty. Of the soils from the Indo-Gangetic alluvium, the silicates of the Changa Manga soil were nearly entirely white; those of the Burdwan soil were nearly entirely white, but included some little black silicates, the Bahr clay soil contained a good deal of black silicates; that of the Dumraon soil was nearly all white, but included a little black silicate. Among the laterite soils the silicates had the following colour: No. 282 mostly white, little black; No. 218, mostly white, some red; No. 280 mostly white, some red; No. 284. mostly dark red. The red colour of these "silicates" was quite different from the dark brown of the *regur* soils, and could not be for a moment mistaken for it. The red soils from Madras Presidency yielded silicates of the following colour: Nos. 327 and 291 mostly white, with a little black; No. 74 mostly white with some red and black; No. 333 mostly white with some red (like the silicates of laterite); No, 250 contained a good deal of black, and No. 331 mostly black. Thus, whilst some of the other soils contained insoluble silicates of a colour similar to that of the *regur* soil, the amount in such cases was always small, whilst, as already observed, the insoluble matter of the *regur* soils was almost entirely very dark brown.

Colour of silicates of different Indian soils.

It need hardly be pointed out that during the process of *boiling* the soil with sulphuric acid all organic matter is destroyed, and that the colour of the resulting "silicates" cannot be due to organic matter or to "organic salts of iron."

STATEMENT No. III.

Analyses of Black Soils (Regur).

District.	Madura District.			Trichinopoly District.	Coimbatore District.	Anantapur District.	
Taluk.	Teramanyalam Taluk.			Parambalur Taluk.	Coimbatore.		Gooty.
	380-96	329-96	330-96	332-96	292-94	114-95	248-96
Insoluble silicates and sand	72·68	68·97	72·89	65·16	69·31	78·50	63·15
Iron (Fe_2O_3)	6·09	6·96	6·27	9·87	5·31	4·34	6·25
Alumina (Al_2O_3)	8·39	10·84	10·84	13·76	8·51	6·33	12·[illegible]
Manganese (MnO)	·19	·22	·20	·25	·20	·21	·15
Lime (CaO)	2·42	1·96	2·20	2·18	4·62	2·00	5·35
Magnesia (MgO)	1·80	1·90	2·01	2·47	2·44	1·95	2·50
Potash (K_2O)	·16	·36	·23	·14	·47	·43	·21
Soda (Na_2O)			·37	·01	1·00	·36	
Phosphoric acid (P_2O_5)	·07	·03	·02	Trace	·19	·03	·06
Sulphuric acid (SO_3)	*Nil.*	*Nil.*	·01	*Nil.*	·06	*Nil.*	·03
Carbonic acid (CO_2)	2·00	·85	1·09	·91	2·77	1·71	3·58
Organic matter and combined water (difference)	6·14	8·61	3·87	5·85	5·12	4·24	7·06
TOTAL	100·00	100·00	100·00	100·00	100·00	100·00	100·00
Nitrogen	·019	·030	·025	·024	·027	·016	·043

STATEMENT No. III.—*continued.*

Analyses of Black Soils (Regur).

District.	Kistna District.					Karnool District.			Cuddapah District.	Central Provinces.	
Taluk.	Guntur.	Guntur.	Sattenapalle.	Narsaraopet.	Narsaraopet.	Cumbum.	Ramallakot.	Pattikonda.	Pulivendla.	Nagpur Farm.	
										Surface soil.	Sub-soil.
	72-96	73-96	76-96	77-96	78-96	80-96	247-96	249-96	252-96	276-96	277-96
Insoluble silicates and sand	72·32	71·66	70·58	64·92	68·29	71·94	63·74	64·91	56·68	68·71	67·01
Iron (Fe_2O_3)	6·67	6·64	7·04	6·60	6·96	5·60	6·54	6·33	8·74	11·25	11·50
Alumina (Al_2O_3)	8·50	8·74	10·61	10·91	10·20	8·62	11·83	9·99	12·77	9·39	10·41
Manganese (MnO)	·14	·12	·18	·10	·09	·12	·16	·16	·22	·26	·25
Lime (CaO)	1·44	1·16	1·67	3·53	3·43	3·31	3·66	4·90	4·95	1·82	1·76
Magnesia (MgO)	2·06	2·39	2·02	2·55	2·67	1·94	2·78	2·35	3·09	1·79	2·10
Potash (K_2O)	·68	·48	·68	·79	1·14	·64	·43	·28	·67	·43	·30
Soda (Na_2O)	·31		·31	·57	1·30		·21	·05			·01
Phosphoric acid (P_2O_5)	·07	·06	·05	·07	·08	·08	·05	·07	·08	·06	·05
Sulphuric acid (SO_3)	*Nil.*	*Nil.*	*Nil.*	*Nil.*	*Nil.*	*Nil.*	*Nil.*	·01	*Nil.*	*Nil.*	*Nil.*
Carbonic acid (CO_2)	·16	·16	·49	1·96	1·88	2·40	2·32	3·15	3·43	·44	·53
Organic matter and combined water (difference).	7·65	8·59	6·37	8·00	3·06	5·35	8·28	7·80	9·37	5·83	5·79
Total	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00
Nitrogen	·049	·036	·020	·030	·012	·045	·034	·035	·028	·050	·04

18. After obtaining the results here detailed regarding the composition of the *regur* soils, I submitted a copy to the Director of the Geological Survey, and I add here copies of Mr. Oldham's letter on the subject and my reply.

Copy of a Demi-official letter dated 3rd September 1897, from Mr. Oldham *to* Dr. J. W. Leather.

Correspondence with Mr. Oldham.

"I return herewith the extract from your report on *regur* with thanks for the favour of being enabled to see it. I trust you will arrange that we are supplied with a copy when printed. As regards your ideas, it is of course impossible to judge fully from a mere extract. To take one point only, I think, from what I have seen, that the dark colour is not due to humus, but an important element in deciding this is the determination of the amount of organic carbon in the soil. From the extract you send it would seem that this was not determined, but this is probably in another part of the report.

The following points, however, struck me :—

(1) With a single exception, none of your samples came from the typical *regur* areas of the Deccan trap plateau in Bombay, Berar and Malwa. The one exception, the sample from Nagpur, is from the extreme limit of the area. The identity of the Madras cotton soils with the true *regur* has been doubted, and as it is to the latter, as developed in the plateau of the Deccan trap, that the Manual principally refers, some of your criticisms are easily explained.

For instance, the divergence you notice between Tween's analyses and yours is due to this. In the districts where his analyses show an excess of iron over alumina, this is, I should say, a general feature, and is in agreement with your single analysis.—Nagpur,—from the same region. The Madras cotton soil I would expect to contain less iron if they agree with the other in mode of origin.

The remark in the Manual about the fertility of the soil has special reference to the region from which you have no samples. I think it is probable that the general impression which it records is explicable as you explain it, but there can be no doubt of the general idea as to the fertility of the soil, an idea which is crystallised in the term Malwa, applied to the great spread of it north of the Nerbada.

(2) Though I think it probable that the dark colour is not due to humus, it might yet be due to organic matter, as organic acids in combination with ferrous salts give dark-coloured compounds—

e.g., ink—and a soil composed of decomposing basic minerals would naturally contain ferrous compounds.

(3) The concluding part of your extract is, I must confess, inexplicable to me, for I know of no dark-coloured silicate whose specific gravity is less than any white silicate, and unless our accepted ideas of chemical and physical constitution are erroneous, do not see how such could be the case. It seems clear that the particles with which you were dealing could not be silicates, or there must be a slip in your account and you have inverted the behaviour of the black and white particles.

These are the three principal points which struck me in reading your note, which is very interesting, but I must regard it as a matter of regret that the absence of specimens from the great and typical area of Berar and Malwa make the report inconclusive, as it deals exclusively with soils which have only been classed with the true cotton soil on the ground of superficial resemblance. Some of these are certainly of a different origin, and apparently quite different in their characters too, and all of them are only to be doubtfully related to the true cotton soil, from which they differ in chemical composition—very probably also in origin."

Copy of a demi-official letter No. 159, dated 21st September 1897, from Dr. J. W. Leather *to* R. D. Oldham, Esq., *Calcutta.*

"Thank you for your demi-official of 3rd instant.

Doubtless it would have been an advantage to have analysed more samples of *regur* from the Central Provinces and Berars, but still I have seen these *regur* plains, as well as those in Madras, and so far as one can judge by appearances only, there are no particular differences between them. *Regur* seems to be a soil which is so characteristically different from any other sort of soil, that even when impure, such as when it is merging into another soil on its margin, one cannot have any doubt as to whether a part is *regur* or not. But the samples which I analysed were, so far as I could judge, *pure regur*. In any case the mere variation in the relative proportions of iron and alumina can hardly affect the principal question at issue. For instance, it may be that in one large area, there is more iron than alumina, in another the reverse proportions. I do not see how it can be suggested that the *regur* in Madras is essentially different from that in the Central Provinces and

Berar or Malwa, when the principal physical features of the two are identical!

2. I notice that you still think it possible that the black colour is due to the presence of "organic salts of iron." Well, I can only point out, as I have done in my report, that in my opinion no such compounds could exist under the influences of an Indian climate. The example which you give, namely, *ink*, would become rapidly oxidised.

3. Then about the dark-coloured material which I have spoken of as a "silicate." There can be no doubt of its existence, and in another experiment which I made, I again found *white* silicates sink in a dense liquid, whilst the dark-coloured material remained floating. I was of course very much surprised at this, for I naturally expected the black stuff to be the denser.

But apart from this, the most important feature is the fact that these *regur* soils, on being boiled for some hours with concentrated sulphuric acid, remain almost entirely black, whereas all ordinary soils become white with such treatment. The black colour cannot of course be due to carbon."

19. One of the first experiments which I made with the siliceous residue of these *regur* soils, obtained, as already detailed, by the action of concentrated sulphuric acid, was to try to separate the black material from the white.

Separation of silicates of *Regur*.

The method by which such a separation may be effected is briefly as follows. A strong solution of some heavy metallic salt is made which has a greater specific gravity than the silicates concerned. There are several solutions which may be prepared for this purpose. The one which I employed was prepared by dissolving mercuric iodide in a solution of potassium iodide. This had a specific gravity of 2·526 at $\frac{15°C.}{1500.}$. Most of the siliceous residue from *regur* floated on the surface of this liquid; that which sank was white. By cautiously adding small quantities of water, or better, of a solution of potassium iodide, the solution becomes less dense, and when a certain point is reached, the densest (specifically heaviest) matter, which had been floating, sinks. I naturally expected that the *black* material would prove denser than the white, and I was much surprised to find that the reverse is the case.

Method.

Several experiments have been carried out with the mixed siliceous matter of a number of these *regur* soils, and the result has proved to be uniformly the same. In every case the densest material was white and this sank first. My Experiments.

By carrying out the method of separation in careful steps, the siliceous matters were separated into half a dozen portions, all of which had decreasing densities. In the two quantitative separations which are detailed below, the first fraction was nearly white, the second grey, the third, fourth and fifth nearly quite black, and then curiously the last or lightest portion was lighter coloured.

The weights of the materials thus obtained were as follows:—

First experiment.—From 2,200 grammes of the silicates, ·558 grammes (white); ·030 (nearly white); ·389 (dark coloured); ·616 (very dark coloured); ·085 (somewhat lighter coloured); ·522 (grey) were obtained.

Second experiment.—From 25·897 grammes of silicates the following fractions were obtained; 3·452 (white); 2·182 (nearly white); 1·333 (grey); 1·656 (nearly black); 6·765 (blackest); 5·425 (dark grey); 5·084 grammes (light grey).

The black material was now subjected to the following further tests:—

(a) Under the microscope it proved to be by no means all black, but the particles consisted of apparently silicate with a red and a black substance fused to them. The quantity of black particles was not by any means so large as one would have expected from the colour of the substance as a whole. But as is well known, it does not require a very large proportion of a black material, when mixed with a white one, to render the whole quite black to the naked eye.

(b) On igniting the black siliceous material it became red. Under the microscope it was observable that the black particles had disappeared.

(c) On treating the black material with concentrated hydrochloric acid at 100° C. for an hour or so, a certain amount of iron is dissolved, but the colour of the whole remains unchanged. Under the microscope it appeared that the black particles remained, but the red particles had diminished greatly.

(*d*) If the black material be first ignited and then treated with concentrated hydrochloric acid at 100° C., practically just the same amount of iron becomes dissolved as was the case with the unburnt black siliceous matter, but whilst the latter remained black, this burnt material became quite white. Under the microscope no red or black particles conld now be seen.

Black particles possibly graphite.

There can be little doubt that the black particles are either volatile or oxidisable, but it is doubtful whether they contain any iron at all. The iron which the black siliceous matter gives up on treatment with hydrochloric acid, both before and after ignition, is doubtless also an adhering constituent of it. I have not had an opportunity of carrying the investigation any further. It is possible that the black particles consist of graphite, fused on to the silicates, but this will require to be proved.

These experiments had not been completed when Mr. Oldham saw my manuscript, and they will explain probably that it is quite possible for the dark-coloured siliceons matter to have a less density than the white. At any rate, there is not the least doubt that the black particles are in part composed of silica, and also that they have a less density than the white. Otherwise the latter could not have sunk first in the separating fluid.

OTHER "BLACK" SOILS.

20. Among the samples of soil which I have received from Madras are three or four which are either described as "Black Loams" or have a similarity in colour to the *regur*, but which are certainly not *pure regur*. They vary much in composition and appearance. The analyses are set out In Statement No. IV.

No. 79-96 is described as "*regur* loam; locally known as *Pati-mannu* which is specially preferred for the cultivation of tobacco and chillies. It is from this sort of soil that saltpetre is manufactured."

Descriptions of samples.

Regarding this remark, I must say that the sample contained no trace of nitrates, and, as will be evident from the analysis, there was very little nitrogen in it at all. It is a very dark-coloured sandy soil containing about 1 per cent. of calcium carbonate, much less iron and alumina and magnesia than *regur*; the amount lost on

heating is also very small, and indeed is a very poor soil in every respect excepting in that of phosphoric acid, of which the proportion is high.

It is not particularly surprising that no nitrates were present, because I imagine that the remark applies not so much to the particular land from which the specimen was selected, as to the fact that nitrates are found in similar soil *in another situation*. But it is somewhat surprising that it should be described as a good soil for the cultivation of chillies and tobacco, since land which is retained for the growth of these crops is usually kept in good "heart" by liberal allowances of manure. The assessment is entered as R*1*-o-o which is low, and one must assume that *this particular field* is not utilised for the purpose in qnestion, but rather that similar land of other fields are kept for it.

No. 328-96 is described as "black loam (called *Ilakkali pottal*); it conserves moisture very well. The soil was whitish on the surface. Cotton thrives on it." It is a grey sandy soil containing very little organic matter and nitrogen and phosphoric acid, and one would not have expected it to "conserve moisture well."

No. 251-96 is described as a "red loam; hard and saline and grey coloured; requires light and frequent showers; called locally *Tella kattu nela*." The term "red" is donbtless a clerical error. It is a grey soil full of fine *kankar* and pieces of rock, but having also something of the appearance of *regur*. Indeed the analysis indicates this, the silicates are low, the iron and alumina high—the proportion of carbonate of lime high (the carbonic acid is equivalent to 6·90 per cent.), the high magnesia, with alkalis and phosphoric acid, loss on heating and nitrogen, all in similar proportion to that in *regur*, in short a composition which could not by itself be distinguished from a good *regur*. It is probable that this is a true *regur* containing enough *kankar* and coarse rock to give it the texture of a loam rather than a good "black cotton soil."

No. 75-96 described as "*regur* clay, locally known as *Yerra masaka*." The soil had a dark brown colour and differed somewhat in appearance from true *regur*, though doubtless there was some *regur* in it. It has nevertheless a general composition similar to *regur*, and a very fair proportion of phosphoric acid.

STATEMENT No. IV.

Analyses of Black Loamy Soils.

	KISTNA DISTRICT.	MADURA DISTRICT.	KARNOOL DISTRICT.	KISTNA DISTRICT.
	Vinu Konda Taluk.	Teramanylam Taluk.	Patti Konda Taluk.	Gunter Taluk.
	79-96.	328-96.	251-96.	75-96.
Insoluble silicates and sand	90·70	82·11	59·45	73·83
Iron (Fe_2O_3)	2·53	5·70	9·08	9·09
Alumina (Al_2O_3)	2·18	5·19	11·86	6·60
Manganese (MnO)	·06	·12	·12	·14
Lime (CaO)	1·13	1·10	4·41	·88
Magnesia (MgO)	·65	1·27	3·18	1·53
Potash (K_2O)	·37	·24	·56	·20
Soda (Na_2O)	·06	·86		
Phosphoric acid (P_2O_5)	·32	·06	·05	·17
Sulphuric acid (SO_3)	*Nil.*	·15	·06	*Nil.*
Carbonic acid (CO_2)	·45	·93	3·04	·14
Organic matter and combined water (difference)	1·55	2·27	8·19	7·43
TOTAL	100·00	100·00	100·00	100·00
Nitrogen	·006	·008	·036	·047

THE RED SOILS OF MADRAS.

21. Several samples of soil of a distinctly red colour have been sent from Madras, and their composition is exhibited in the accompanying Statement No. V.

In the "*Geology of India*," (2nd Edition), page 410, the red soils of India are thus referred to:—"The somewhat ferruginous soils common on the surface of many Indian rocks, and especially of the metamorphic formations, would probably never have attracted much attention, but for the contrast they present in appearance to the black soil. They have only been noticed as a rule in papers relating to the black soil country in the Western and Southern portions of the Peninsula. The commonest form of red soil is a sandy clay, coloured by iron peroxide, and either derived from the rock *in situ* or from the same products of decomposition washed to a lower elevation by rain. The term is, however, used in a very vague sense, apparently to distinguish such soils as are not black, and hence many alluvial soils may be comprehended under the general term. In very many cases, too, it appears to have been applied in Southern India to thick alluvial beds of sand or sandy clays, which are in fact ordinary river or rain wash deposits." Doubtless these remarks had no reference to *laterite* soils, which are not only frequently red, but also of peculiar appearance. But in addition there are also unquestionably soils of such a bright red colour that they could not for a moment be confused with any alluvium. The first six soils in the Statement are of this colour. **Bright red colour.**

No. 291-94 was a brick-red gravelly soil with the rock very near the surface. **Descriptions of Samples.**

No. 327-96 is described as a "Red loam; red sandy soil. The plant called in Tamil *Melagapundu*, resembling chillies, is a common weed on this soil. It is said to be intoxicating to cattle."

No. 250-96 is described as "Red sand, called locally *Yerra nela;* needs frequent and copious rainfall for the successful cultivation of crops."

No. 333-96 "Red sand; wild indigo grows luxuriantly on the soil. The soil is not far from a hill."

No. 378-96. "Red sand; overlies a bed of gravel at a depth of 2 to 3 feet; is poor; called in Tamil *pottal; Cholum* and *Samai*

(Panicum miliare) are the chief crops; natural herbage scanty; becomes somewhat hard and compact in dry weather, unlike most sandy soils, and in that condition emits a peculiar hollow sound when dug with the *mamooty*. This soil is infested with white-ants, every stalk of the stubble of the last *cholum* crop being covered with ant-hills."

No. 379-96 "Red sand, similar to No. 378, but does not become so hard when dry, nor is it so infested with white-ants, natural herbage good. Considered fit for ground-nuts. *Ragi* does not thrive on this soil.

General composition. It will be observed that five of these soils contain higher proportions of iron and alumina than is common to "sandy" soils. The amount of organic matter and nitrogen is also very small, the lime is only very moderate in amount, and the phosphoric acid is distinctly low.

No. 74-96 is described as a "Red loam, locally called *Garuvu*. Average depth of soil is 2 feet."

Although this soil contains about as much iron as some of the others of this class, the proportion of alumina is very small. Generally regarding these soils it will be seen that the amount of lime is small or only moderate, the magnesia is not high and the phosphoric acid is uniformly low. On the other hand, the proportion of ferric oxide and alumina is usually high. Indeed their composition is in many respects very similar to the laterite soils (para. 22), the chief feature of dissimilarity being in the respective proportions of phosphoric acid. Whilst the laterite soils contained very varying amounts of this valuable plant food, its proportion in these red soils was very uniform, the extreme variation being between ·05 and ·07 per cent.

STATEMENT No. V.

Composition of Red Soils from Madras Presidency.

DISTRICT.	COIMBATORE.	MADURA.	KURNOOL.	TRICHINOPOLY.			KISTNA.
Taluk.	Coimbatore.	Dindigul.	Pati Konda.	Parambalur.	Trichinopoly.		Guntur.
	291·94.	327·96.	250·96.	333·96.	378·96.	379·96.	74·96.
Insoluble silicates and sand	80·33	90·47	68·10	86·74	88·84	85·99	89·31
Iron (Fe_2O_3)	5·18	3·51	6·38	5·70	4·55	7·09	5·90
Alumina (Al_2O_3)	7·50	2·92	15·84	5·68	3·46	3·19	1·57
Manganese (MnO)	·10	·08	·07	·10	·06	·08	·08
Lime (CaO)	1.11	·56	·79	·48	·10	·16	·46
Magnesia (MgO)	·65	·70	·80	·70	·38	·28	·30
Potash (K_2O)	} ·36	·24	·23	·05	} ·28	·11	·45
Soda (Na_2O)		·12	·19	·15			
Phosphoric acid (P_2O_5)	·09	·09	·06	·05	·04	·11	·08
Sulphuric acid (SO_3)	*Nil.*	*Nil.*	*Nil.*	*Nil.*	*Nil.*	*Nil.*	*Nil.*
Carbonic acid (CO_2)	·85	·30	·20	·11	·03	·08	·10
Organic matter and combined water (difference)	3·83	1·01	7·40	·24	2·26	2·91	1·75
TOTAL	100·00	100·00	100·00	100·00	100·00	100·00	100·00
Nitrogen	·021	·006	·051	·021	·001	·005	·018

LATERITE SOILS.

22. In the accompanying Statement No, VI, are set out the analyses of a number of soils which have been named as "laterite" by the senders.

Origin of laterite uncertain.

When summing up the evidence as to the origin of laterite Mr. Oldham (*Geology of India*, page 385) writes: "From what has gone before it will be seen that the subject of the origin of laterite is still wrapt in obscurity. None of the various hypotheses that have been propounded is completely satisfactory, nor is it possible to come to any final conclusion till an agreement is come to as to the meaning of the word laterite."

If then it is difficult for the Geologist to decide what is "laterite," it becomes practically impossible for the agriculturist to say what is a "laterite soil."

Those "laterite soils," that is, soil lying on or adjacent to what had every appearance of being laterite rock, which I have seen, had all a bright red appearance when dry; but as will be seen when discussing the analyses of the samples which I have examined, some at least of these are probably not true laterite.

23. The following are the descriptions of the soils:—

Description of samples.

No. 218-96 is the surface soil of a field at Saidapet, Madras. The soil consisted of a coarse brick-red gravel. It will be observed that there is practically no lime, no phosphoric acid, and a very small proportion of nitrogen.

Nos. 280-96 to 283-96.—These four samples, two of surface and two of sub-soil were sent by the Deputy Commissioner of Hazaribagh. When sending them he worte: "I have the honour to submit two samples of laterite soil, or the nearest approach to it, since laterite soil cannot be found in this district."

All the samples were, however, of a bright red soil. They contain comparatively much manganese, and more lime than any of the other laterite soils examined, though for agricultural soils they are not by any means too well off in this particular. The amount of phosphoric acid is very low, being less than $\frac{1}{100}$ per cent. in three of them. The proportion of nitrogen, though higher than in some of the other laterite soils, is, nevertheless, low from the agricultural point of view.

Nos. 284 and 285-96.—These two, a surface and a sub-soil, were received from the Deputy Commissioner of Lohardaga and were selected by the District Engineer, who wrote: "The accompanying specimens, I believe, are of the laterite soil of this district or a fair representative of it. As far as I have seen, the soil is not a compact mass, but loose and gravelly, that is a mixture of pebbles of various sizes and dust; sometimes there are compact blocks mixed with the gravel; a specimen of a block is herewith submitted. As a rule these pebbles appear to be partially fused and at places there are fragments of quartz and (rarely) other rocks mixed with them. Three specimens are sent herewith.—*1st*, surface soil taken within 12 inches depth (No. 284-96); *2nd*, sub-soil 12 to 24 inches in depth (No. 285-96); *3rd*, a compact block found mixed with the loose soil (not analysed)."

The reference to the pebbles appearing partially fused is an indication that this is a true laterite gravel, the "fused" appearance being due to a crust of limonite in them. The analyses indicate that both the surface and sub-soil are so rich in iron that they might with more propriety almost be called iron ores.

The amount of alumina, though higher than in the alluvial soils of India, is not more than in the other *laterite* soils here referred to.

The proportions of lime and magnesia are low; so also is the nitrogen. The loss on heating is naturally high, owing to the high proportion of hydrated peroxide of iron. The phosphoric acid is quite unusually high in comparison with other Indian soils.

No. 358-96 is a surface soil sent by the Deputy Commissioner of Singbhum and described as laterite. It also contained a very high proportion of iron and is doubtless of lateritic origin. The sub-soil which was pink, had the general appearance of laterite. This soil also contains very little lime and magnesia, and the amount of phosphoric acid is as small as in many other Indian soils.

Nos. 360-96 to 367-96 were eight samples of soil, four surface and four sub-soil, sent by the Deputy Commissioner of Manbhum District, Chota Nagpur. Only the surface soils were analysed.

Nos. 360 and 361 are described as "*Purulia*" *tand* (high land), the former being the surface 8 inches, the latter the sub-soil. It is of a "sandy and gravelly nature." The surface soil, analysis of which is given, consisted of a soft *drab* soil, more like alluvium than anything

else; the "sub-soil" simply consisted of pieces of quartz with ferruginous veins here and there, and had no similarity to the laterite which I have seen at Madras and the Deccan. The composition of the surface soil is merely such as one would expect any alluvium to have and is devoid of striking peculiarities.

Nos. 362 and 363 are the surface 9 inches, and sub-soil of what is described as *Bengabara land* (high land). "The land is of a sandy and gravelly nature." The surface soil 9 inches, No. 362, was similar in appearance and colour to No. 360. Its composition is similar to No. 360 in most respects, but the proportion of phosphoric acid is higher and it contains more nitrogen. The sub-soil (not analysed) was a grey lumpy earth with some little pieces of rock intermixed.

Nos. 364 and 365 are described as "*Simalia land* (high land)." "The land is a sandy and gravelly high land almost free from grass and other weeds" No. 364, the surface 9 inches, was a brown soil; the sub-soil No. 365 was apparently laterite rock.

Nos. 366 and 367 are the surface 12" and the sub-soil of what is described as *Raghunathpur* (high land) "a mixture of mud, sand and gravel." The surface soil was similar to No. 364 in appearance, and the sub-soil consisted of laterite rock.

These four surface soils are in most respects similar to one another in composition, and excepting that Nos. 360 and 362 were more of a drab colour, whilst 364 and 366 were of a deeper brown, they were similar in appearence.

There is, moreover, nothing in their appearance or composition which is similar to the other "laterite" soils here described, and had it not been for the fact that laterite rock underlies two of them near the surface I should have assumed that they had no connection with laterite at all. Under the circumstances all that one can do is to point out the dissimilarity.

General composition. The other eight samples are probably true representatives of the laterite soils, and the somewhat wide variations in their composition, especially in the proportion of iron, illustrates a feature that one might have predicted, for a rock which itself contains hydrated peroxide of iron (if indeed it does not actually owe its origin to the presence or formation of this substance) might naturally be expected to lose larger or smaller amounts of it during its decay, the less soluble silicates being left behind. As will be

seen, the amount of ferric oxide varies from 4 up to as much as 48 per cent. The amount of manganese appears to be sometimes higher than in soils generally; lime is in no case abundant, and generally it is deficient. The amount of phosphoric acid varies greatly. In two of the eight samples it is unusually high for Indian soils, but in four it is *very* deficient, and in the others the amount is lower than one might wish. Lastly, there is in no sample any large amount of organic matter or nitrogen, though in some of the samples the latter is present to the same extent as it is in *regur*.

STATEMENT No. VI.

Analyses of Laterite Soils.

	Saidapet, Madras.	Hazaribagh District, Bengal.		Hazaribagh District, Bengal.		Lohardaga District, Bengal.		Singhbhum District, Chota Nagpur.	Manbhum District, Chota Nagpur.			
		Surface soil.	Sub-soil.	Surface soil.	Sub-soil.	Surface soil.	Sub-soil.	Surface soil.	Surface soil.	Surface soil.	Surface soil.	Surface soil.
	218-96.	280-96.	281-96.	282-96.	283-96.	284-96.	285-96.	358-96.	360-96.	362-96.	364-96.	366-96.
Insoluble silicates and sand	76·86	78·62	74·84	80·46	76·96	29·67	33·66	59·06	90·07	85·30	90·39	90·34
Iron (Fe_2O_3)	10·09	6·35	6·96	6·12	6·40	48·71	42·08	26·64	4·37	5·68	2·90	3·17
Alumina (Al_2O_3)	18·84	8·98	11·57	7·19	11·31	8·81	13·89	7·37	2·39	4·00	4·40	2·95
Manganese (MnO)	·19	·39	·28	·50	·33	·07	·06	·48	·09	·11	·09	·06
Lime (CaO)	Trace	1·50	·96	1·72	·94	·38	·45	·28	·14	·47	·14	·38
Magnesia (MgO)	·77	·66	·81	·38	·51	·21	·20	·33	·31	·60	·28	·36
Potash (K_2O)	·09	·43	} ·70	·38	} ·44	·10	} ·27	·27	·14	·40	·19	·25
Soda (Na_2O)	·17	·81		·32		·04						
Phosphoric acid (P_2O_5)	Trace	Trace	Trace	Trace	·04	·64	·26	·08	·13	·30	·04	·06
Sulphuric acid (SO_3)	*Nil.*	*Nil.*	*Nil.*	*Nil.*	*Nil.*	*Nil.*	*Nil.*	*Nil.*	*Nil.*	*Nil.*	*Nil.*	*Nil.*
Carbonic acid (CO_2)	·12	·12	·08	·12	·05	·06	·12	·16	·28	·06	·05	·38
Organic matter and combined water (difference)	2·87	2·74	3·80	2·81	3·02	11·31	9·01	5·43	1·98	2·88	1·33	2·05
TOTAL	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00
Nitrogen	·015	·039	·032	·030	·026	·010	·010	·024	·016	·032	·031	·036

COFFEE SOILS.

24. The accompanying Statement No. VII. exhibits the composition of some soils from a coffee estate in the Sheveroys, Madras, which Mr. C. G. Loehler very kindly sent me from his Brooklyn Estate It will be observed that one is of newly broken up jungle land, one from land which had borne coffee for two years, two of land which had been under coffee for twelve years, and two which had borne the crop for forty years. Source.

In physical appearance these soils were all similar, consisting of a nice open soil with a good admixture of organic matter. And, as might be expected, they are, in general composition, alike. The amount of iron and alumina, especially the latter, is unusually high (they are in no sense clays), the amount of lime very low, alkalis only in moderate amount. Appearance.

In the matter of the important plant foods, organic matter and nitrogen, and phosphoric acid they are well supplied. Moreover, comparing the soils, which had been many years under coffee, with the newly broken jungle land, it will be seen that the soil has not suffered any very serious loss by the process. They all contain somewhat less phosphoric acid and a little less nitrogen (in two cases a good deal less) than the newly broken up jungle, but excepting in the case of No. 372, which contained only ·05 per cent. phosphoric acid, the differences are not great, especially when it is remembered that the samples are not from one small area, but from different parts of the estate, and one cannot of course assume that the land was in each case precisely like No. 371. Doubtless the fertility of the land has been maintained by the careful and constant manuring which the coffee planters provide. Composition.

STATEMENT No. VII.

Analyses of coffee soils from Yarcand—Sheveroy Hills—Madras Presidency.

	Jungle land cleared this year.	Two years under coffee.	12 years under coffee.	12 years under coffee.	40 years under coffee.	40 years under coffee.
	371·94.	369·94.	367·94.	368·94.	370·94.	372·94.
Insoluble silicates and sand	56·31	57·85	52·61	56·84	59·72	58·31
Iron (Fe_2O_3)	11·92	9·08	10·10	10·60	9·13	9·77
Alumina (Al_2O_3)	17·31	19·74	19·94	18·62	17·88	18·34
Manganese (MnO)	·09	·06	·07	·07	·07	·09
Lime (CaO)	·32	·30	·35	·34	·31	·44
Magnesia (MgO)	·53	·38	·53	·51	·56	·66
Potash (K_2O)	·20	·14	·15	·21	·31	·89
Soda (Na_2O)	·08	·02	·07	·06		·03
Phosphoric acid (P_2O_5)	·20	·10	·14	·12	·13	·05
Sulphuric acid (SO_3)	*Nil.*	*Nil.*	*Nil.*	·05	*Nil.*	*Nil.*
Carbonic acid (CO_2)	·10	·02	·10	·09	·03	·03
Organic matter and combined water (difference)	12·94	12·28	15·94	12·49	11·86	11·99
TOTAL	100·00	100·00	100·00	100·00	10·00	100·00
Nitrogen	·170	·043	·158	·150	·065	·154

S. 2260 a.

TEA GARDEN SOILS.

25. A note on Indian soils would not be complete without a somewhat detailed reference to the composition and characters of the soils of the tea districts which were examined some few years ago by Mr. H. K. Bamber, F.C.S., when Chemist to the Indian Tea Association, Calcutta, and whose book *On the Chemistry and Agriculture of Tea* was published in 1893. Source of information.

From the chapter on soils I have extracted the information contained in the following paragraphs.

From the Dooars Mr. Bamber analysed four soils, in three of which the sub-soil was also examined, and the Statement No. VIII. exhibits their composition. The following are brief descriptions of them. No. 1 was a soil of the Dam Dim district, and was planted with tea in 1890 (apparently just before the analysis was made). "It was a reddish sandy loam, in a fine state of division containing much potash, mica and occasional fragments of granitic and slaty rocks. The land was naturally well drained and the young plants were healthy and strong. The soil before being opened carried good timber forest." Dooar soils.

No. 2 was "a soil from the same district, but had been under tea for some years, greyish colour, very finely divided and full of mica. The bushes were fairly healthy, but had fallen off in yield, partly owing to age, and partly to the readily available plant food having been largely used up."

No. 3 "A soil from another district in the Dooars. This was very light and friable consisting chiefly of quartz and micaceous sand, and had little retentive power for moisture. The sub-soil was similar in character to the soil, but rather more stony and open. It was found that tea plants in this soil died out in the dry season, and even when planted in the rains only produced a small sickly growth."

No. 4. "A soil from the Dooars, on which tea would not grow during the wet season. It was of a light grey colour, in a very fine state of division, had a soapy touch, and when moistened with water, set almost like a cement. The iron was present almost entirely as the lower poisonous oxide, and this together with the large amount of impalpable matter and silicate of magnesia, which, when wet

SOILS.

On the Composition of

STATEMENT No. VIII.

Composition of Four Soils from the Dooars.

	(1)		(2)		(3)	
	Dam Dim District. Forest land newly planted with Tea. Reddish sandy loam. Young tea vigorous.		Dam Dim District. Similar to No. 1, but had born tea for some years and the yield had fallen off.		Dooars a light sandy soil full of quartz and micaceous and Tea died out in hot weather owing to lack of moisture.	
	Surface soil 18"	Sub-soil 3ft.	Surface soil 18"	Sub-soil 3ft.	Surface.	Sub-soil.
Organic matter and combined water.	5·95	4·44	7·27	5·39	8·19	6·17
Sand and silicates	78·35	80·73	77·55	79·64	80·19	83·87
Soluble silica	1·04	·60	...	...	...	...
Lime (Ca O)	·07	·16	·17	·15	·06	·06
Potash (K_2O)	1·02	·30	1·91	·71	·54	·41
Manganese	...	·40	1·26	2·17	trace.	trace.
Alumina	7·27	9·04	} 12·16	} 11·81	} 10·92	10·04
Oxide of iron (Fe O)	6·52	4·26				
Phosphoric acid (P_2O_5)	·09	·07	·09	·05	·10	·05
TOTAL	100·31	100·00	100·41	99·93	100·00	100·00
Containing Nitrogen equal to ammonia.	·344	·19	·365	·134	[illegible]	·10
Containing Nitrogen equal to Nitric acid.	·004	·0003	trace.	trace.	...	...

(4)

Dooars.
A very fine soil, which when moistened with water, set like cement. Tea failed during the rains.

Moisture	5·000
Organic matter and combined water.	8·735
Sand and silicates	79·636
Carbonate of lime	1·083
Potash	1·330
Magnesia	1·800
Iron and alumina	6·042
Phosphoric Acid	·170
Soda, etc.	·083
	100·00

would choke the rootlets and prevent the absorption of plant food and was the probable cause of the tea bushes dying out as soon as the rainy season commenced."

26. A class of soils called *bhil* appears to be more or less commonly met with in Assam and Cachar. The corresponding English term would be "Peaty" soils and the unbroken *bhil* soils, Nos. 5 and 15, as exemplified by the analyses quoted in the accompanying Statement No. IX. contain large proportions of organic matter and were very acid. Bhil Soils

The following descriptions of the soils referred to are taken from Mr. Bamber's book.

No. 5. "A rich *bhil* soil from Assam (Nowgong district) which was very favourable for the growth of tea. It had highly retentive properties, both for moisture and manurial matter, owing to the large amount of organic humus substances and alumina contained in it. It contained only a trace of lime, however, and apparently would be benefited by an application of that constituent, as a certain quantity is removed annually by the leaf. To prevent hastening the destruction of the organic matter, the lime in this case, would be best applied as carbonate, as the soil had only a very slight acid reaction when moistened, from the organic salts present."

No. 6. "A soil from the same district as the above which had grown tea for years and was still yielding well."

No. 7. "Another soil from the same district under young tea yielding a large outturn."

No. 11. "This was a heavy clay loam of average fertility that had been under tea for several years."

STATEMENT No. IX.

Composition of Samples of Bhil Soils (Assam).

	(5)	(6)	(7)	(11)	(13)	(15)	(16)	(17)	(18)
	Nowgong. Rich Bheel soil, good for tea.	Nowgong. Had been under tea for some years.	Nowgong. Young tea doing well.	Haila Kandy District, Cachar. Heavy clay loam of average fertility.	North Cachar, Low Bheel land. Blue clay.	Central Cachar. Newly opened Bheel soil.	From same flat as No. 15. Under tea five years.	From same flat as No. 15. Under tea six years.	From same flat as No. 15. Under tea six years.
Organic matter and combined water	14·74	4·30	4·70	2·13	3·90	34·29	4·21	10·81	15·40
Sand and silicates	70·10	85·47	86·49	78·37	84·75	53·04	89·62	79·73	74·37
Soluble silica	·94	...	...	...	·17	·03	·01	·09	·05
Lime	trace	trace	trace	·14	trace	·07	trace	trace	·03
Potash	·81	·41	·30	1·85	·31	·50	·27	·30	·39
Magnesia	·24	·50	·50	·90	1·08	·37	·11	·08	·27
Manganese	1·82	·58	·75	·21	...	...	...	...	...
Alumina	9·28	5·12	1·03	9·16	3·56	10·31	5·08	8·44	8·40
Oxide of iron	2·00	3·06	5·71	7·00	6·07	·83			
Soda	...	...	...	...	...	...	·21	·18	·79
Phosphoric acid	...	·56	·52	·24	·16	·50	·48	·34	·32
TOTAL	100·03	100·00	100·00	100·00	100·00	100·00	99·98	100·00	100·00
Nitrogen equal to Ammonia	·694	·253	·257	·22	·13	1·19	·164	·374	·576
Nitric acid	·001	trace	·0003	...	·001	·005	...	...	...

No. 13. "A soil from the same garden (as No. 12 North Cachar) taken from low flat *bhil* land between the *teelas*. It was a compact stiff blue clay, coloured partly with organic matter and partly with the lower oxides of iron, which required oxidation to remove their poisonous properties. Where it had been opened out and thoroughly drained, the character of the soil became changed, and tea grew on it luxuriantly; but from the poorness of the soil in nitrogen, it would probably soon require a dressing of some manure containing that constituent, such as the various oil cakes, in order to keep up the outturn. Lime, as carbonate or sulphate (gypsum) would also be beneficial, but in the case of tea, magnesia appears to be capable of replacing lime to a certain extent, and the soil is fairly well supplied with that constituent."

No. 15. "A rich newly opened *bhil* soil from the same estate (as No. 14 Central Cachar) nearly black in colour when wet, greyish when dry, very hygroscopic and retentive of moisture, when moistened it had an exceedingly acid reaction, which required neutralisation with lime, either in the caustic or mild state."

Nos. 16, 17, 18. "The following three analyses were made of soils taken from the same flat or lay of land as No. 15, but which had been planted out with tea in different years . . . . , No. 16 had been under tea about five years, and Nos. 17 and 18 six years."

27. Another description of soil which is met with in Assam is called "*Teela*." Judging by the composition of those mentioned by Mr. Bamber, they are poor sandy soils. The first two analyses in Statement No. X. are of this class. No. 12 was "a soil from North Cachar. This is a very sandy ferruginous soil, from a *teela* that had been under tea for several years, and from which the original surface soil had been largely removed by drainage. It is exceedingly poor in almost every plant constituent, and would require the frequent application of large quantities of general manures to increase the outturn of leaf. Similar soils are sometimes much improved by a heavy top dressing of *bheel* soil, rich in organic matter and nitrogen, but owing to the excessive drainage from the sharp slopes, and the small retentive power of the sandy soil for any manurial matter, most of it would be washed away from the plants before they could utilise it, and the benefit derived would be only temporary." *Teela soils.*

STATEMENT No. X.

Composition of other Tea Garden Soils.

	(13) Teela Soil from North Cachar had been under tea for several years.	(14) Teela Soil, Central Cachar, had been under tea for several years.	(19) Darjeeling, Kurseong District.
Organic matter and combined water	2·66	3·78	11·26
Sand and silicates	92·17	89·63	70·23
Soluble silica	·01	·12	...
Lime	trace	·06	·25
Magnesia	·04	·23	trace
Potash	·20	·21	2·90
Soda	...	...	...
Manganese	·06	...	·13
Oxide of Iron	2·09	3·26	5·97
Alumina	2·73	2·37	9·27
Phosphoric acid	·04	·20	·27
Sulphuric acid	trace	trace	...
TOTAL	100·00	99·86	100·00
Nitrogen equal to Ammonia	·068	·124	·335

No. 14. "A soil from Central Cachar, very finely divided ferruginous sandy soil from an old *teela* which had been under tea for several years and was similar in character to No. 13."

No. 19. "A soil from the Kurseong District, dark in colour very hygroscopic, containing much potash-mica, and fragments of easily disintegrating micaceous rock."

Description of Bhil and Teela soils.

28. It would appear that the soils of the Tea Gardens vary very much in composition and character, as might well be expected from the fact of their position being either in the hills or in their immediate neighbourhood. The two extreme variations are represented by the *bhil* and *teela* soils. The former are, especially when first opened out, peaty, and consequently consist largely of organic debris with high proportions of nitrogen. The latter (*teelas*) are sandy. Speaking of the former Mr. Bamber says:— "Peaty soils, such as are found in Cachar and Sylhet, but more rarely in

Bhil soils.

Assam, have a marvellous power of causing tea to yield rapid and heavy flushes, but such tea is not of very good quality and has little or no flavour. But after they have been opened out, drained

and cultivated for two or three years, the quality of the tea gradually improves without the quantity decreasing to any extent. When first opened out, these soils are very rank and sour in character, due to the want of proper oxidation by the air, which has been prevented by the dense undergrowth of the jungle excluding the air, and to the presence of an excess of stagnant water in the soil itself. By the burning of the jungle, when cut, a large quantity of mineral matter is given to the soil in the form of carbonates, which assist in neutralising the acid humic matters contained therein, and rendering the soil fit for the growth of cultivated plants. This change is also assisted by the cutting of deep drains to remove all stagnant water containing effete and poisonous matters in solution.

Sour at first.

Improvement.

The depth of *bhil* soils varies from 2 feet to 10 feet or more, and usually below them there is a dense sub-soil of blue clay, the colour being due partly to certain organic substances, and partly to the presence of the lower oxides of iron, which are distinctly poisonous to plants. When the soil is not very deep and the roots of the tea are likely to penetrate to a sub-soil of the above description, it would be necessary first to dig drains of some depth into the sub-soil, and so cause aëration and oxidation of the iron compounds, otherwise when the roots of the plants descended, they would absorb these poisonous constituents, which would either check their growth or kill the plants entirely.

Depth.

Drainage.

Peaty *bhil* soils undergo a great change and loss when under cultivation, due to the combined action of the air and rain on the organic matter, which is rapidly oxidised to carbonic acid, and either washed away or given into the atmosphere as gas. Owing to this rapid and serious loss of organic matter and nitrogen, it is necessary to adopt some means of lessening it as much as possible, and this would be best done by limiting the amount of cultivation or hoeing given throughout the year. It must be remembered that these soils are already very light and porous, and when well drained admit air freely into their interior, so that cultivation is not so necessary as when the soil is more compact, and need only be done to bury the jungle when it attains a size, that would interfere with the growth of the bushes. By adopting such a system, the amount of organic

Changed by cultivation.

matter decomposed would be almost, if not quite, replaced by that obtained from the atmosphere by the buried jungle, and deterioration of the soil would be largely prevented. The well-known luxuriant growth of tea or other plants on such soils is due in a great extent to the rapid decomposition of the organic matter, which affords an abundant supply of carbonic acid for the use of the growing plant." . . . "Some *bhil* soils which have been opened out and planted with tea are very heavy in character, being composed almost entirely of a stiff blue clay, which at first has a most unpromising appearance; however when deeply drained at close intervals and thoroughly cultivated for a year, the character of the surface soil undergoes a change in appearance and becomes more gritty and sandy, from the removal of a part of the almost impalpable matter in the soil. This alteration in character proceeds gradually deeper into the sub-soil as the drains become more active, until at last the blue colour almost entirely disappears, having changed to a pale and gradually deepening yellow.

Some *bhil* soils are clayey.

When this change has taken place, the soil appears to grow tea luxuriantly, and such a soil will probably prove far more lasting than the peaty *bheel* soils mentioned above, owing to its retentive character for the bases liberated by cultivation and exposure of the soil to the atmosphere.

Drainage water acid.

The drainage water from most newly opened *bhils* contains much oxide of iron, which is present in the soil in the form of the lower oxide, and which is gradually deposited after exposure to the atmosphere as the higher or red oxide. It is also invariably very acid, owing to the presence of several organic acids in solution, which are very detrimental to the healthy growth of tea, and should be removed by drainage, or neutralised by lime, prior to any bushes being planted out.

Value of lime.

If this precaution is not taken, it frequently happens that, although the plants live, their growth is checked for some months until the necessary changes have taken place, and it will be found that such plants will never flush or grow as luxuriantly as those which are planted after the soil has been sweetened by drainage and cultivation."

Value of *bhil* soils on other land.

29. An application of *bhil* soil as manure to lighter soils, such as the *teelas*, has proved very beneficial. For instance, speaking of the soil No. 15 (*vide* Statement No. IX.), Mr. Bamber says :—"When dry this soil is richer in plant food than the cattle manure obtained in this country, and its application as a top-dressing has proved very beneficial to tea bushes on worn-out *teela* soils."

Teela soils.

30. Describing the *teela* soils, Mr. Bamber says :—"Another class of soils on which tea is largely grown, are the light *teela* soils on which tea was first planted when introduced into Cachar.

Effect of surface wash.

Some of these soils when first cleared must have been fairly rich and strong, from the appearance of the jungle and forest growing on uncleared *teelas* at the present time, but they have in almost every case rapidly deteriorated, more from the amount removed by wash and heavy rainfall than from what has been removed by the tea itself.

When protected from direct rainfall by the jungle growth, they gradually increased in richness and value in the same way as other forest soils, but after the jungle was cleared away and the surface soil loosened by cultivation, they were washed down from the summit and slopes of the *teelas*, and helped to form and enrich the *bhil* soils beneath.

Terracing.

Attempts have been made with a certain amount of success to prevent this wash by terracing the slopes of the hills, but in many cases this was only done, when the best of the soil had been washed away, and the effects were not so beneficial as they would have been had the terraces been made when the *teelas* were first cleared.

Usually light.

The character of these *teela* soils does not vary much, being generally a light sandy loam, formed from the decomposition of the laterite rock beneath, but occasionally the soil rests upon a pebbly sub-soil, which fact, together with the sharp slopes, makes drainage too excessive, so that the bushes are very liable to suffer from drought, in any but a very wet season.

In a few instances the base of the *teelas* is formed of a dense whitish clay, which yield a soil very unsuitable for the successful growth of tea, but the outcrop of such a soil is usually very small in extent, and beyond its effect on the drainage of the *teelas* in which it occurs, its presence is of little importance."

Chemical composition.

31. Regarding the composition of the tea garden soils generally, it will be observed that they are much better supplied with the plant foods, phosphoric acid and nitrogen, than are any of the other classes of Indian soils which I have examined, excepting in the case of the Coffee soils from the Sheveroys.

Nitrogen. *Phosphoric acid.*

The soils of the Dooars, as represented by the analyses quoted in Statement No. VIII., contain from ·1 to ·35 per cent. of nitrogen; the proportion of phosphoric acid is somewhat low in certain of them and varies from ·05 to ·17 per cent. But the *bheel* soils all contain much higher proportions of these plant foods. The *teela* soils seem to vary a good deal. The soil No. 12 is undoubtedly poor, but the other one of this class No. 14 contains a very ample supply of both phosphoric acid and nitrogen.

Potash.

The supply of potash in these tea garden soils appears to be ample, as indeed I have found generally in Indian soils.

Lime.

32. The particular ingredient which seems to be most deficient in the Assam soils generally is lime. Mr. Bamber remarked on this and set out in a separate statement (No. XI. of this paper) the proportions of lime found in all the soils which he examined. From this statement it will be seen how very small is the amount of lime throughout.

STATEMENT No. XI.

Proportion of Lime in Tea Garden Soils.

	Assam.	Cachar.	Kangra.	Darjeeling.	Dooars.	Chota Nagpur.
1	trace.	trace.	·38	·48	·14	·01
2	"	"	·39	·15	·30	...
3	"	"	·06	...	...	...
4	"	"	·17	...	...	...
5	"	·19	·12	...	...	...
6	·10	·11	·58	...	...	...
7	·15	·12	...	...	...	...
8	·31	·05	...	...	...	...
Average per cent. of Lime . .	·07	·06	·29	·32	·22	·01

In Appendix 44 of Mr. Bamber's book the cost of *burnt* lime is estimated at R112 to R128 per 100 maunds, with an additional R15 to R30 for carriage, to which has to be added the cost of the earthen jars in which it is packed. One hunded maunds per acre

Cost of liming.

would be equivalent to about 0·2 per cent. of lime in the first foot of soil, and this would cost about R150. To bring about a radical change in soils which contain so little lime, it is probable that 200 maunds would have to be applied so as to raise the percentage to about 0·5. But it is also probable that *unburnt* limestone, ground up so as to pass through ¼ inch sieve, would produce the desired effect, and the cost of this might be considerably less than the above. Another point which I do not see noticed in Mr. Bamber's book is the question whether one could not effect a remedy without the aid of lime, by burning some of the soil near gardens which require lime, or at least a free alkali. The part which the lime would play in such soils as those under notice, would be to keep the land "sweet," *i.e.*, prevent it from becoming sour. In England the process known as "pearing and burning" is employed. The surface soil is collected in heaps, mixed with fuel and burnt. The combustion is "slow" and the temperature is not allowed to rise sufficiently to burn the clay to brick, but merely high enough to liberate some of the alkalis and alkaline earths. It seems possible that this might be done in the neighbourhood of gardens, and the burnt earth applied to take the place of lime.

Pearing and Burning.

THE POONA (MANJRI) FARM SOIL.

33. Samples of the soil of the field at Manjri (Poona) which is devoted to sugarcane, were taken prior to the commencement of the experiments in 1894, and the proportions of nitrogen, phosphoric acid and potash determined in them. The accompanying Statement No. XII. sets out the results of those analyses.

STATEMENT No. XII.

Analyses of Soils from Manjri, Poona.

	Plots 2 and 3.	Plots 5 and 6.	Plots 8 and 9.	Plots 13 and 14.	Plot 22.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Total Nitrogen . . .	·014	·034	·031	·024	·035
Total Phosphoric acid . .	·031	·025	·014	·028	·016
Available Phosphoric acid .	·010	·010	·005	·008	·010
Available Potash . . .	·008	·008	·005	·009	·016

Composition. The proportions of nitrogen and phosphoric acid (total) are low. The amounts of available phosphoric acid and potash are probably sufficient for ordinary crops, but they are not high; about one-third of the total phosphoric acid is readily "available."

THE NAGPUR FARM SOILS.

34. Samples from three plots at this farm were selected in 1896, and the amounts of the principal plant foods determined in them.

These are set out in Statement No. XIII.

Composition. The proportion of nitrogen is slightly higher than that in most *regur* soils; that of *total* phosphoric acid is about average.

The proportion of *available* phosphoric acid varies. In the surface soil of Plot A-4, which has been regularly manured, there is a very fair amount, but in the surface soil of Plots A-8 and A-7 there is very much less. Plot A-8 has been regularly manured by ploughing in a green crop, but it must be recollected that this system of manuring adds no phosphoric acid to the soil, though one might have anticipated that this procedure would have occasioned an accumulation of *available* phosphoric acid. Plot A-7 has remained unmanured, and the low proportion of *available* phosphoric acid is readily understood. The amount of *available* phosphoric acid in the sub-soil of all the plots is low.

The percentage of available potash is fair in all the samples.

STATEMENT No. XIII.

Analyses of Soil from the Nagpur Experimental Farm.

	PLOT A-4 MANURED WITH 6 TONS OF CATTLE MANURE PER ACRE PER ANNUM.		PLOT A-8 MANURED WITH GREEN HEMP PLOUGHED IN ANNUALLY.		PLOT A-7 UNMANURED.	
	Surface soil.	Sub-soil.	Surface soil.	Sub-soil.	Surface soil.	Sub-soil.
	Per cent.	Per cent.	Per cent	Per cent.	Per cent.	Per cent.
Total Nitrogen .	·065	·033	·045	·033	·050	·047
Total Phosphoric acid	·093	·065	·078	·058	·064	·054
Available Phosphoric acid.	·020	·008	·008	·004	·007	·005
Available Potash .	·021	·010	·016	·010	·012	·010

THE CAWNPUR FARM SOIL.

35. A number of samples of the surface soil of certain of the experimental plots at Cawnpur have been analysed. Statement No. XIV. sets out the results.

The effect of the manures has been to materially raise the proportion of nitrogen. The proportion of phosphoric acid has not been generally increased. Of the total phosphoric acid from ⅙ to ¼ is available, excepting in the case of the two plots which have been regularly manured with Indigo "Seet." Effect of manuring.

The proportion of available potash is fairly high in most cases.

THE DUMRAON FARM SOIL.

36. When the new land at Dumraon was taken up in 1895, samples of the surface soil and sub-soil were taken from eight spots, four in the Northern half and four in the Southern half, and the amounts of the principal plant foods determined in each.

A complete analysis of the mixed surface soil samples, and one of the mixed sub-soil samples, was also made.

The following Statement No. XV. sets out the results.

The quality of the land was remarkably uniform, and coincides generally with soils of the Gangetic alluvium. Of the total phosphoric acid, about ⅕ was *available* in the surface soil, but in the subsoil the proportion available was considerably less than this. Land uniform.

STATEMENT No. XIV.

Analyses of the Soil of the Cawnpur Experimental Farm.

	Total Nitrogen.	Total Phosphoric Acid.	Available Phosphoric Acid.	Available Potash.
	Per cent.	Per cent.	Per cent.	Per cent.
Unmanured Plots.				
Rabi Standard No. 11	·024	·085	·021	·012
Kharif Standard No. 13	·016	·053	·082	·007
Alternate Series A No. 13	·017	·088	·030	·007
Ditto B No. 11	·023	·071	·014	·012
Green Manure Series No. 5	·017	·052	·015	·027
Manured Plots.				
Rabi Standard No. 3 } Each manured annually with 180 maunds or 14,400 lbs. of cattle dung per acre.	·031	·067	·032	·012
Kharif Standard No. 3 }	·065	·094	·047	·027
Alternate Series A No. 6 }	·024	·072	·036	·012
Ditto B No. 3 }	·042	·072	·025	·019
Green Manure Series No. 2 (Ma nured annually with 120 maunds or 9,600 lbs. per acre of fresh Indigo seet.)	·038	·089	·009	·011
Green Manure Series No. 1 (Manured annually with 120 maunds or 9,600 lbs. per acre of old Indigo seet.)	·107	·079	·008	·007

STATEMENT NO. XV.

Analyses of the Dumraon (new) Farm.

	Surface soil 1"-9".				Sub-Soil 9"-2' 9".			
	Nitrogen.	Total Phosphoric Acid.	Available Phosphoric Acid.	Available Potash.	Total Nitrogen.	Total Phosphoric Acid.	Available Phosphoric Acid.	Available Potash.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
North half of Farm—								
North	·043	·069	·015	·013	·043	·076	·008	·006
South	·047	·066	·009	·009	·049	·071	·005	·010
East	·042	·063	·012	·010	·037	·074	·005	·008
West	·047	·099	·083	·013	·039	·084	·006	·009
South half of Farm—								
North	·041	·081	·012	·009	·041	·065	·003	·007
South	·043	·c86	·021	·010	·039	·124	·010	·009
East	·042	·077	·015	·012	·039	·067	·004	·007
West	·049	·089	·017	·015	·039	·071	·006	·010

	Surface soil.	Sub-soil.
Insoluble silicates and sand	86·73	80·78
Soluble silica	·09	·12
Iron (Fe_2O_3)	4·09	6·12
Alumina (Al_2O_3)	4·57	6·50
Manganese (MnO)	·10	·14
Lime (CaO)	·30	2·07
Magnesia (MgO)	·76	1·17
Alkalis (K_2O Na_2O)	·48	·73
Sulphuric acid (SO_3)	...	...
Phosphoric acid (P_2O_5)	·08	·08
Carbonic acid (CO_2)	1·07	2·29
Organic matter and combined water	1·73	
TOTAL	100·00	100·00
Nitrogen	·049	·041

S. 2260 a.

GENERAL CONCLUSIONS REGARDING THE COMPOSITION OF INDIAN SOILS.

37. Having now examined individually the composition of the several different classes of soil, it will be well to summarise the deductions which may be drawn from the information thus supplied and at the same time compare them with the opinion of Indian soils at which Dr. Voelcker arrived from an examination of such few analyses as were at his disposal when writing his report.

Silicates.—The proportion of silica and silicates was determined by digesting the soil (after gentle ignition) in concentrated hydrochloric acid, and it may be here remarked that they were in all cases (even those of the *regur* soils) quite white after this treatment.

Alluvial Soils. In the soils of the great Alluvial Plains, their amount is much about the same as one is accustomed to find in English loams and clays. Regur. In the Black cotton soil (*regur*) their amount is uniformly low; due principally to the high proportions of ferric oxide and alumina and the water combined with them, and to a lesser degree to the presence of larger amounts of lime and magnesia than many English loams contain. Red Soils. In the Red Soils of Madras the proportion of silicates is low in two cases, due to the presence of large amounts of iron and alumina; the other samples contain high amounts. Laterite. The laterite soils yielded very varying amounts of insoluble silicates, which was due almost entirely to the great variations in the amount of iron and alumina which is a chief characteristic of these soils. Madras alluvium. In the Brown Alluvial soils from Madras Presidency, the proportion of silicates is low in the loams, chiefly owing to the high proportions of iron and alumina which these soils contain. Coffee Soils. In the Coffee soils from the Sheveroys the silicates are very small in amount, due in part to high proportions of iron and alumina, but in part also to high proportions of organic matter. Assam Soils. In the Assam soils, the proportion varies very much, according to the proportion of organic matter present.

Iron usually high. *Iron.*—The amount of Iron which exists in Indian soils appears to be in all the classes examined higher than what one is accustomed to meet with in English soils. In the soil of the Indo-Gangetic alluvium it occurs in proportions varying from 2 up to 7 per cent. In the *regur* its proportion varied from 4 up to 11·5 per cent. In the Madras red soils it varied from 3·5 to 10 per cent.; in the 8 laterite soils (the

identity of which could not be doubted) from 6 up to 48 per cent., but in the four doubtful laterites it fell to a much lower figure. In six of the Madras alluviums the proportion was from 5 up to 17 per cent. In the Assam soils the proportion varied very much, but was generally high. Lastly the coffee soils contained from 9 to 12 per cent. Thus there can be little doubt that the amount of iron in Indian soils is large, in some very large indeed.

Alumina.—In the case of the alumina, too, almost all the soils examined contained high proportions. In the soils of the great alluvium, it varied from 3 up to nearly 10 per cent.; in the *regur* from 6 up to nearly 14 per cent.; in the red soils there was a good deal of variation, the extreme limits being 1·5 and 15·8 per cent.; in the first eight of the laterite soils it varied from 7 up to nearly 14 per cent., though the four doubtful laterite soils contained much less; in the Madras alluvium it varied from 6 up to 15 per cent. in the loams, but there was much less in the sandy soils. Lastly the Coffee soils contained the very high proportion of 17 to 20 per cent. **Usually high proportion.**

Manganese.—This metal appears to be very widely distributed in the soils of India, though it occurs only in small amount, the proportion in the alluvial soils varied from ·11 to ·30; in the *regur* from ·1 to ·26; in the red soils from ·07 to ·20; in the laterite soils from ·06 to ·50; in the Madras alluviums from ·03 to ·26 per cent., whilst the coffee soils contained from ·07 to ·09 per cent. **Widely distributed.**

Lime.—The proportion of Lime in the soils has been calculated to the oxide for the sake of uniformity. Some of the lime in all the soils exists as carbonate, some part as silicate. As is well known calcareous soils are generally absent from India, the only one of those examined that could fall under this category being the soil from Captain Chapman's estate; the peculiar circumstances under which this soil has been forming have been already alluded to. The soils of the alluvium contained from ·3 to 2 per cent.; the *regur* soils contained more, namely, from 1·0 to 7·7, the greater number of them contained from 2 to 5 per cent.; the red soils, the laterites and the Madras alluvium contained uniformly small proportions, usually less than 1 per cent., the coffee soils had about ·3 per cent., and many of the Assam soils even less than this. Dr. Voelcker writes: "speaking generally, lime is more plentifully distributed in Indian soils than **Calcareous Soils rare.** **Alluvium.** ***Regur.*** **Laterite.**

in English; that is, deficiencies are not so frequently met with. A notable exception, however, which I have found is in the laterite soil of parts of Southern India such as the coffee-growing districts of Coorg and Mysore, and the Tea Plantations in the Nilgiris, where, I have reason to believe, a more abundant supply of lime would be decidedly beneficial." The evidence now afforded by the analyses quoted substantiates this opinion *in the main*. There is undoubtedly sufficient lime in the *regur* soils, and most of the soils of the Gangetic alluvium contained a sufficiency; of the laterites 7 out of 12 also contained a sufficiency, and it was deficient in none of the Madras red soils. These remarks as to sufficiency and deficiency, however, are really based on a European standard, and it must be considered an open question whether it is proper to apply such a standard to Indian soils. One of the chief objects which an English farmer has in maintaining a fair proportion of lime (1 per cent. at least) in his land is the retention of a sufficient amount of free basic matter to combine with the organic acids which are constantly formed from the humus. The proportion of humus in English soils is unquestionably higher, much higher than is the case with Indian soils, and consequently it is open to doubt whether Indian soils usually are in absolute need of so large an amount of lime as one would consider necessary for English soils. Thus I feel certain that the laterite soils, for instance, which contain so little lime, would not be benefited materially by an application of it. On the other hand, the coffee soils from the Sheveroys are somewhat differently placed. The *total* amount of lime present in them is not *very* small, but still it is not large and most of this exists as silicate. These soils contain also a very considerably greater proportion of humus than other soils from the plains, and it *may* be that such land as this would be benefited by an application of lime. The Assam Tea garden soils would, I feel certain, be very greatly benefited by an application of this substance.

Usually sufficient.

European standard considered in relation to Indian Soils.

Generally Plentiful.

Magnesia.—Dr. Voelcker's remark that "Magnesia appears to exist in sufficient abundance throughout, and more plentifully than in English soils" (paragraph 64) is amply confirmed. In the soils of the Gangetic alluvium it seems to be generally present in amount exceeding 1 per cent. The *regur* soils contained even more than

this. in two samples only did the proportion fall appreciably below 2 per cent., and in one case it ran up to 3 per cent.; indeed in these soils its amount is singularly uniform, nearly all the samples containing from 2 to 2½ per cent. The red soils contained usually about ½ per cent. There appears to be less of this element in the laterite soils than in the other classes referred to.

Potash.—The proportion of Potash appears to be ample in all classes of soils. Ample Potash.

38. *Phosphoric acid.*—From the few analyses which Dr. Voelcker had at his disposal he concluded that phosphoric acid is "more abundantly distributed in Indian than in English soils," and he suggests that ·12 or ·13 per cent. would be a good average for English soils. Of the ten analyses which Dr. Voelcker had at his disposal, five contained more than this amount and five a little less than this. The lowest was ·09 per cent. Among the samples which I have examined, the majority contained considerably less than Dr. Voelcker's standard. Of the Gangetic alluvial soils, six contained ·08 or less, four contained from ·09 to ·13, and only two, namely, the Changa Manga soil and the calcareous one, both of which had been placed for long periods under influences of accumulation of plant food contained more than ·13 per cent. Of the eighteen *regur* soils, sixteen contained ·08 or less of this plant food, the other two containing about ·20 per cent. Of the six red soils, four contained ·08 per cent. or less, the remaining two ·09 per cent. Of the laterite soils, four contained less than ·01 per cent. four others ·08 per cent, or less, and four others fair amounts. The Madras alluvial soils contained, as a whole, somewhat more, there being ·08 per cent. or more in six out of ten samples, but the other four contained only very small amounts. The coffee soils have doubtless been well manured, and contained with one exception ·1 per cent. or more. The Assam soils appear to be far better off in respect of phosphoric acid than any other soils in India. In none of those examined could there be said to be a serious deficiency. My samples usually contained less Phosphoric acid than Dr. Voelcker's.

Thus as regards the amount of phosphoric acid, it is obvious that most of the soils of India are not abundantly supplied, but rather it must be admitted that the amount is frequently small. Glancing, too, at the analysis of the farm soils, it will be seen that the land at Manjri Usually low proportion.

(Poona) contained, when first taken up for the sugar-cane experiments, ·03 per cent. or less of total phosphoric acid (paragraph 32), and the soil of the (new) Dumraon Farm about ·08 per cent. when first taken up (paragraph 35). On the other hand, exceptions to the general conclusion as to the usually low proportion of phosphoric acid in Indian soils, are found in the case of the Assam soils and those of the Meerut District. The soils from the Meerut District contained (*vide* paragraph 45), very distinctly larger amounts of this plant food. Some of them contained as much as ½ per cent., eighteen out of the thirty-five contained ·1 per cent, or over, and only two contained less than ·06 per cent.

39. ***Available Phosphoric acid.***— Although the knowledge of the total amount of phosphoric acid in a soil acts as a guide to one in forming an opinion as to the desirability or otherwise of supplying phosphates to land, still it has long been recognised that a more accurate means of judging this point would be most valuable.

Dr. Dyer's Investigations.

In 1894, Dr. Bernard Dyer, of London, published an important paper before the Chemical Society, in which he showed that a close relation existed between the amount of phosphoric acid which was dissolved by citric acid, and the known fertility of certain plots at the Rothamsted Experimental Station.

An examination of a large number of the roots of plants showed that the acidity of the sap was on the average equivalent to very nearly 1 per cent. of citric acid, and Dr. Dyer then submitted certain of the Rothamsted soils to the action of a 1 per cent. solution of citric acid for seven days. He took as his standard soil, the surface soil of the field in which barley had at the time been grown continuously for 40 years. The Rothamsted experiments have yielded such uniform results that the relative agricultural fertility of the several plots was well known.

Method.

The treatment of the soil for seven days with citric acid was admittedly empirical, but what Dr. Dyer aimed at was to demonstrate whether the result of such treatment would correspond at all with the known fertility of these standard soils.

The result of this research showed conclusively that a very close correspondence existed between the amount of phosphate

thus dissolved from these soils, and their known fertility in the matter of phosphates.

A second part of the investigation consisted in answering the same question in relation to potash, and in this case likewise a close relation was made apparent between the amount of potash soluble in 1 per cent. citric acid solution, and the known requirements of the land for this plant food.

Meaning of available Phosphoric acid.

The potash and phosphoric acid in soils which is thus dissolved by citric acid is styled the "available" potash or phosphoric acid. Dr. Dyer examined twenty-two soils in this manner, and he concluded from his research that "when a soil is found to contain as little as about ·01 per cent. of phosphoric acid soluble in a 1 per cent. solution of citric acid, it would be justifiable to assume that it stands in immediate need of phosphatic manure."

Only certain of my samples tested.

Although for want of time, the amounts of phosphoric acid and potash rendered soluble by 1 per cent. solution of citric acid have not been determined in all the samples of soils which were considered typical of Indian agricultural land, the determination of the total and available phosphoric acid was carried out on some of the farm soils and in the case of the soils of the Meerut district. We have thus five sets of determinations of this "available" phosphoric acid, two in *regur* soil (Manjri and Nagpur), and three in the alluvium, (namely, Meerut, Cawnpur and Dumraon), and although these cannot be considered to be so fairly representative of Indian soils as those in Statements Nos. I. to XI., still it would seem that a conclusion may be drawn from them indirectly as to the amount of "available" phosphoric acid in certain classes of Indian soils.

The amount of total phosphoric acid has been shown to be low in most Indian soils as judged by a European standard. The further question now presents itself, "How much of the phosphates in Indian soils is available?"

Bearing in mind the standard which Dr. Dyer has proposed, namely, ·01 per cent. of "available" phosphoric acid, we may glance at the analyses of the Meerut and other soils in which both the *available* and *total* phosphoric acid have been determined.

Meerut Soil

Of the thirty-five soils from the Meerut district only two fell below the standard. Of the samples from the field at Manjri (when taken up

Manjri, Cawnpur.

in 1894), only one contained appreciably less than ·01 per cent.; of the samples from the Cawnpur Farm, none of those from plots which had remained for 15 years without manure contained so little as the ·01 per cent. limit, and most of them a good deal more; and of the soils from the Dumraon Farm when taken up in 1895, only one contained less than the standard (namely, ·009 per cent.).

Dumraons.

Most of the Meerut soils doubtless contain much more than an average amount of phosphoric acid, and may, for the moment, be set aside. The Manjri soils contained no large amount of total phosphoric acid (only ·015 to ·03), indeed very decidedly less than what *regur* soils have been shown to generally contain. The soil of the new Farm at Dumraon contained about ·06 to ·08 per cent. total phosphoric acid, which is much about the same as the soils of the alluvium have been shown to contain generally; and the soils from the unmanured plots at Cawnpur, containing from ·05 to ·08 per cent. total phosphoric acid, have also much about an average allowance. Thus it is seen that, although the only soils in which the *available* phosphoric acid has been determined are from but a few places, the farm soils are not exceptionally rich in *total* phosphoric acid. Whilst therefore it is admitted that these are examples of soils from five particular spots, it is nevertheless evident that the percentage of total phosphoric acid in the soil of the farms is not abnormal, and that they cannot be said to be *exceptional* soils.

Proportions "available."

A further point may now be taken into consideration, namely, "what proportion of the total phosphoric acid in these Indian soils is "available?" and is that proportion about the same or different from what Dr. Dyer found to be the case in the Rothamsted soils? Looking over Dr. Dyer's analyses, I see that of the total phosphoric acid in the soils of the *manured* plots, about $\frac{1}{4}$ or $\frac{1}{5}$ was "available," whereas in the case of the unmanured plots, only about $\frac{1}{10}$ of the total phosphoric acid was "available."

The Indian Farm soils which have been referred to are examples of either unmanured, or at least but very *slightly* manured land, and in no case equivalent to the *manured* plots at Rothamsted, rather, on the contrary, do they more nearly approach to the unmanured plots at Rothamsted.

Turning now to the analyses of these soils, in those from Manjri from 1/5 to 1/3 of the total phosphoric acid was "available;" in the Dumraon soil about 1/4 of the total phosphoric acid was "available;" in the unmanured Cawnpur Farm soils, from 1/4 to 1/3 of the total phosphoric acid was 'available; in those of the Meerut soils, which contained large amounts of phosphoric acid, the proportion is very much higher; in those containing less phosphoric acid, the proportion varies generally from about 1/4 to 1/3. In the unmanured land at Nagpur, only about 1/10 was available, but in this case a process of exhaustion had been going on for some years. Thus it is seen that, although most of these soils (excluding the rich Meerut soils) contained rather small percentages of *total* phosphoric acid, they not only generally contain more than the standard ·01 per cent. of "available" phosphoric acid, but also that the *relative* amount of "available" phosphoric acid is high. **Usually up to Dr. Dyer's standard.**

It has been pointed out that the farm soils named are, in no particular exceptional, and indeed they may be considered as fair samples of the Gangetic alluvium and of the *regur*, respectively; it may then be fairly assumed that in these two great types of Indian soils about 1/3 or 1/4 of the total phosphoric acid is generally "available." The importance of these considerations will become the more evident if reference is now made to the analyses of the alluvial and *regur* soils in Statements Nos. I. and III.

It will then be seen that if 1/4 of the total phosphoric acid be generally "available", it is only rarely that we find a soil deficient in this plant food, and thus, although the Indian soils have frequently or generally a low proportion of *total* phosphoric acid, it is likely that the proportion of *available* phosphoric acid is not usually deficient. **Probably alluvium and Regur usually contain enough "available" Phosphoric acid.**

It would of course not be proper to assume a similar deduction for the red soils of Madras and the laterite soils, since the "available" phosphoric acid has not been determined in any soil of these two classes.

The deduction regarding the amount of *available* phosphoric acid is also quite in accord with the fact that at one farm only (namely Burdwan) have bones been found to be of any service as manure. At each of the other four farms bones have regularly been applied to certain plots in the field experiments, and in no case has it been found that a materially increased outturn results from the application. **This does not apply to other types.**

Little Sulphates.

40. *Sulphuric Acid.*—Like phosphoric acid, when sulphuric acid is present in a soil, it always exists in combination with some one or other of the metallic oxides with which it forms sulphates. There is usually no simple means of determining with which base it is associated, and for purposes of ready expression, its amount is calculated in the form of the anhydride. The majority of Indian soils (excluding of course those which are impregnated with soda salts) contain remarkably little sulphate, and its amount was in no case as much as 1 per cent.

Carbonic Acid.—This was determined in order to see to what extent the lime exists as carbonate. This constituent need hardly be referred to here; it has already been pointed out that its amount is usually less than sufficient to combine with the lime, and that consequently it may be assumed to be in combination principally with that oxide.

Meaning of this term.

41. *The Organic Matter and Combined Water.*—The figure indicating the amount of these two items in the statements are in all cases the difference between thesum of the other ingredients and 100 per cent. The loss which the soils experienced on heating was determined in all cases, and differed but little from the figures quoted. Although certain deductions in some cases can be made regarding the relative proportions of the true organic matters or humus contained in the soils, and the amount of the water which is chemically united with them, the knowledge of the loss by combustion of a soil does not serve as a means of even approximately determining the amount of that most valuable constituent humus. It may be said, however, that in the event of any soil containing a fair proportion of organic material, the fact is readily observable to the operator who watches the appearance of the soil when placed in a receptacle over the lamp.

Referring in the first place to the amount of "organic matter and combined water" in the several classes of soils, among the alluvial soils, there are two clays which suffered a material loss, but not more than such clays would be expected to suffer, and the greater part is doubtless due to the expulsion of water; these two soils are, however, doubtless in fairly good condition and the amount of organic matter is probably higher than in most. The soil from Changa Manga and that from Captain Chapman's doubtless contained a good deal of

accumulated humus, but as I have already explained they have been placed under quite exceptional circumstances. All the other soils of this class undoubtedly contain but small amounts of organic matters.

Usually little organic matter in alluvium.

The *regur* soils uniformly suffer a greater loss on heating than do those of the alluvium. I have already dealt with the question as to whether much of this may be attributed to organic matter or not in the para. 13, devoted to *regur*, and need only say here that the amount of humus in them is probably quite as small as the soils of the alluvium. The loss which the red soils of Madras and the laterite soils experienced, varied very much indeed, but it will have been noticed that it is high only in those cases in which the amount of iron and alumina are high; a similar remark applies to the alluvium from Madras Presidency, and taking into consideration the general appearance of these soils it may be safely said that the amount of organic matter is usually very small in them. The coffee soils from the Sheveroy Hills undoubtedly contained a high proportion of organic matter. Their appearance indicated it, the amount of nitrogen which they contain is considerably higher than in any of the other classes of soils examined, and all doubt on the point is removed by their appearance on burning. Finally, the *bhil* soils of Assam appear to contain very high proportions of organic matter, especially when first taken up. The *teela* soils of the same province contain only small proportions. Dr. Voelcker came to the conclusion that, with the exception of *regur*, Indian soils are deficient in humus, but even as regards *regur* he says "That it has peculiar powers there is no question, but that it is so rich in vegetable matter and in nitrogenous ingredients as to be independent of manure I do not think".

Probably little humus in Regur.

41. *Nitrogen.*—Glancing over the figures which represent the percentage of nitrogen in the various classes of soils, it will be seen that with the exception of the Assam soils, those from Partabgarh and Changa Manga and those from the Sheveroys, which cannot be considered as typical of Indian soils generally, there is in no case so large an amount of nitrogen as 0·1 per cent. Among the soils representing the Gangetic alluvium, 3 out of 10 contain ·05 per cent. or a little more, the rest less; among the alluvial soils from Madras, two contained about 0·1 per cent. and two contained about ·05 per cent. but in the

Usually little nitrogen

other six samples the proportion was much less. Of the 18 samples of *regur* soils, one only contained ·05 per cent., the other 17 containing less; among the red soils from Madras one contained ·05, the other 5 less; among the 12 laterite soils not one contained as much as ·05 per cent., and most of them only about ·03 per cent. or less. On the other hand the Assam soils contained uniformly high proportions of nitrogen, and those soils which have had an opportunity of accumulating nitrogen contained very fair amounts. The soil from Partabgarh contained ·18, the surface soil at Changa Manga ·237 and the coffee soils from the Sheveroys ·04 to ·17. Thus the opinion to which Dr. Voelcker came, namely, that Indian soils are generally very deficient in nitrogen content is amply supported. Moreover, if the analyses of the other soils which are quoted in paras. 32-35 namely, the farm soils, and those from the Meerut district, be examined, the same tale is told. Among the soils from the Meerut district (para. 45) some of the clays contained more than ·05, but none so much as ·1 per cent., and the proportion in the more loamy soils falls considerably below ·05 per cent. The soil at Manjri (Poona) when first taken up for the Sugar-cane experiments contained ·035 per cent. or less (*vide* para. 33) The soil of the new Farm at Dumraon contained about ·045 per cent. (para. 36).

Dr. Voelcker's opinion supported.

SPECIAL CASES.

43. The following special cases relating to soils have been submitted to me:—

The first is one of some land in the Amherst District, Burma, which is thus described by the Settlement Officer.

Copy of a letter No. 93-1—26, dated 1st April 1896, from the Settlement Officer, Amherst District, Maulmein, to the Reporter on Economic Products to the Government of India.

Burmese soil near hot springs.

I have the honour to advise the despatch to your address on the 28th ultimo of a case containing certain specimens of soil and water connected with the cultivation of onions and tobacco, which would probably be of some interest.

In the neighbourhood of Yebu village, Gyaing Attaran township, Amherst, are some hot springs or tanks of boiling water, a description of which will be found in the *British Burma Gazetteer*, *Vol. 1.*

Description of locality.

The springs are found in low rising ground in the middle of an inundated plain, and the soil immediately round them is laterite. In the immediate neighbourhood of these tanks from which the water bubbles off on the low ground below or is carried into the river *Attaran* by a nullah, are cocoa-nut and betel-nut plantations. The cocoa-nuts have the same flavour as those found near the salt water in the Gulf of Martaban. The soil is only about four feet in depth, and below that water is reached. I send you a specimen of sub-soil No. 3 about eight inches below the surface. On the lower ground on either side the water is too deep in the rains to work any crop, but immediately the water subsides, drains are dug round the plantations and the surface soil dug up with a *mamoti* and the earth thrown up in ridges, on which onions are planted; the crop is taken in February and then a crop of tobacco and chillies, mixed with maize and country vegetables is planted. The specimens now sent were taken in the month of March while the second crop was on the ground, and are, first, a specimen of low lying surface soil No. 1 (*b*) taken from Nga Kannas' field in which a crop of tobacco mixed with maize is planted after the onion crop was taken, and secondly, a specimen No. 2 of high lying hard soil taken from Nga Gunnas' field, in which chillies and country vegetables were planted after the onion crop was taken; about two feet to three feet below the soil, water is reached. The cultivators say that they cannot work the same soil more than five to six years continuously, and not as long as that. The soil gets worn and the crop is poor and will not produce without a long rest. I cannot, however, give any confirmation of this. They say that, if salt water is let into the fields again, it has no fertilising properties, and the land cannot be continuously worked by this means. I also send a specimen of the boiling water from the springs, No. 2, and of water taken from the drain leading past the cultivation No. 3. I should be glad if you could let me know the result of any analysis you make for insertion in the Settlement Report.

The onions grown are the small red onions and sell at Rs. 10 to Rs. 15 per 100 viss,* they say, and the tobacco sells at Rs. 1 per viss, local sale. The cultivation covers only a small area.

The following report which was subsequently submitted, explains the composition of the water and soils in question.

* One viss equals 3·65 lbs. Avoirdupois.

SOILS. **On the Composition of**

The accompanying statements contain the results of the analysis of the samples of water and soils.

	W. No. 2.	W. No. 3.
	Parts per	million.
Total residue	2,750	2,780
Loss on heating	580	570
Oxygen absorbed	12	·6
Sodium Chloride	5	10
Calcium Sulphate	1,485	1,402
Calcium Carbonate	158	133
Sulphates of Magnesia and Alkalis	450	390
Sand	30	60
Sulphuretted Hydrogen	6	0

The water.

Considering in the first place the water, I must explain that "No. 2" and possibly also "No. 3" had changed somewhat in composition before it was analysed. No. 2 contained sulphuretted hydrogen, and this substance changes somewhat easily in contact with the air. No. 3 contained no sulphuretted hydrogen when analysed, but may have contained it when put in the bottle. As the analysis shows, both waters are of practically the same composition, excepting of course in respect of the sulphuretted hydrogen, and they contain very considerable amounts of calcium sulphate (gypsum) with lesser, though still large amounts of sulphates of magnesia and the alkalis. What the exact circumstances may be under which these hot springs are formed, I cannot say. Doubtless, however, the sulphuretted hydrogen is formed by the action of steam and carbonaceous matter on the gypsum, and then as the water flows out of the spring and over the ground, the sulphuretted hydrogen becomes in part dissipated, in part re-oxidised, and the latter combines again to form sulphates.

Sulphuretted Hydrogen.

Composition of the Soils.

	No. 3.	No. 1 (b).	No. 2.
Silicates and Sand	21·35	59·61	65·25
Oxide of Iron	28·11	2·08	1·49
Alumina	4·65	13·11	12·16
Oxide of Manganese	·14	—	—
Lime	18·79	·85	·87
Magnesia	3·00	·72	·63
Potash and Soda	1·06	1·51	1·27
Phosphoric Acid	1·06	·06	·05
Carbonic Acid	13·09	·02	·03
Organic Matter and Combined Water	8·75	22·04	18·25
	100·00	100·00	100·00
Nitrogen	·19	·51	·41

Regarding in the next place the soils, that which is numbered 3 contains a very exceptionally large amount of oxide of iron, also a very large amount of calcium carbonate and a very small proportion of silica. I conclude from the Settlement Officer's letter, however, that it is in regard to the composition of the other two soils, numbered 1 (*b*) and 2, that information is more particularly required. They are quite different from No. 3 and are of a more ordinary description. Both contain a low proportion of oxide of iron and a high proportion of alumina, with a high proportion of organic and nitrogenous matter; the amount of sand is low as also is the amount of phosphoric acid. They are, I imagine, stiff clays, and difficult to work.

No. 3 peculiar.

No. 1(b) and 2 ordinary.

Excepting that the amount of phosphates is low, they are not (chemically) poor soils. But if, as I understand, the water from the hot springs flows over these lands, a reason is apparent why the people find a difficulty in raising crops on these soils. There is nothing more prejudicial to plant life than sulphuretted hydrogen, and if the water brings this over the land, the crops are bound to become affected.

There is, it seems to me, only one way out of the difficulty, and that is to keep this water from the springs away from the land. Whether this is possible, I cannot of course say, but if it be possible, then, I should expect the land to be improved rather than injured by cultivation. It is, however, a soil which will always require good, *i.e.*, expensive, tillage. It is one which requires as much exposure to the sun and air as one can give it.

44. Another case of infertility was referred to me by the Conservator of Forests, School Circle.

Copy of a letter No. 287, dated 5th March 1897, from the Deputy Conservator of Forests, Dehra Dun Division, to J. W. Oliver, Esq., Conservator of Forests, School Circle, North-Western Provinces and Oudh.

I have the honour to send herewith three samples of soil for analysis by the Agricultural Chemist. They were collected by me from the top soils of three separate places in compartments 16 and 17 in the Dholkot Forests.

Dehra soil.

2. I have numbered them both inside and outside.

Sample No. 1 was collected from the top soil of an open glade surrounded by tall *sál* trees, the spot being perfectly open above and within easy reach of falling *sál* seeds.

The spot contained no young growth.

Sample No. 2 was collected from a similar spot, but the young growth was of medium quality.

Sample No. 3 was collected from under a very thick growth of young *sál* trees about 25 feet high.

3. Kindly let me know the results of the analysis.

As the following report shews the infertility of the land was due to natural poverty of the soil :—

Analyses of samples of Soils from the Dholkot Forests.

	No. 1.	No. 2.	No. 3.
Nitrogen (total.)	·043	·101	·152
Available Phosphoric Acid	·026	·028	·048
Total Phosphoric Acid	·105	·112	·144
Calcium Carbonate	·187	·293	·685

The soil No. 3 is the richest and No. 1 the poorest in plant-food, and this will probably explain why the latter does not produce so much young growth.

MEERUT SOILS.

45. In 1895 Mr. Wyer, the Collector of Meerut, sent a number of samples of soil for analysis. It was impossible to make complete analyses of so many, and therefore only the proportions of the most important ingredients were determined. The following is a copy of the report which I submitted on them, and the Settlement Officer's reply is also added.

Copy of a letter No. 426, dated 12th March 1897, from the Agricultural Chemist to the Government of India, to the Settlement Officer, Meerut.

I have now the honour to forward the results of my examination of the samples of soils which were forwarded by Mr. Wyer, on 15th April 1895. (*Vide* statement XVI.)

2. This list is arranged according to the physical characteristics of the soils, and the analyses indicate that, so far as mere chemical constituents are concerned, the clayey soils are the richest in plant-food, which is a characteristic of clay soils generally in other countries.

3. Of course any advantage which a soil may possess in respect of its richness in plant food, may be quite outbalanced by accumulations of the objectionable soda salts, known as "*kallar*" or "*reh.*"

4. I should feel much interested to know in how far the value which you have placed upon these soils agree with the chemical analyses.

Meerut soil Map.

5. I should have been glad to compare the analyses also with the soil map of the Meerut district, which is reproduced in the last settlement report, but the exact places from which the soils were taken has not been forwarded to me. For example, 4 samples were from Loni village, one being a grey clay, another a grey (sandy?) soil, a third yellow "burya" *usar*, and the fourth a yellow sandy soil. The village Loni apparently touches two very different tracts, and therefore I am unable to tell which of these samples belong to one tract, which to the other.

Copy of letter No. 346 A.—3-5, dated 18th June 1897, from the Settlement Officer, Meerut, to the Agricultural Chemist to the Government of India.

I have to thank you for the very interesting list of soil analyses sent with your letter No. 426, dated 12th March 1897, and regret that by an oversight it has been left so long unanswered.

Settlement values.

2. It is rather difficult to answer your question, how far the value placed on the different soils agrees with the chemical analyses. These relative values vary from *pargana* to *pargana* and are affected by several conditions. For instance the outstanding distinction throughout the district is that between irrigated and unirrigated, the difference being often double and never less than one and-a-half; if nearly the whole area is irrigated in any particular tract, it is probable that there will be little difference in the rates paid for good and bad dry soils, the reason being, as I understand, that there are certain crops which are always grown on dry soil, and the necessity of growing these forces up the rate on bad soil almost to the level of the rate on good.

3. The difficulty of answering your question is increased by the fact that the only village on your list which I have examined in detail is Dastoi, *pargana* Sarawa. This is a fairly fertile village, certainly above the average, and I am surprised that the analysis of the soils does not show better results; perhaps they were not typical specimens. Perhaps the best way of giving you an idea of the relative values placed on the different soils is to quote the rates at which land is actually leased in the *parganas* in which I find that most attention is paid to natural

distinctions, Puth and Garhmuktaishar. In these *parganas* the rates are :—

Best loam, irrigated	Rs. 12	per acre.	
„ dry	„ 6	„	
Second class loam, wet	„ 9	„	
„ „ dry	„ 6 to 4-12	per acre.	
Sandy loam or superior sandy soil, wet	Rs. 6	per	acre.
„ „ „ dry	„ 3	„	„
Inferior sandy soil, dry . .	„ 2 to 1-4	„	„
Clay, wet	„ 9 to 6	„	„
„ dry	„ 6	„	„

These are the rates in the best villages but the proportions are much the same, though the rates are lower in those which are inferior.

4. The case of clay may be specially noticed as analysis shows it to be particularly rich in plant-food. Here I can say without hesitation that the relative value I have given for two *parganas* prevails throughout the district. Dry *dakar*, as it is called, pays as high a rate as the best dry soil, wet *dakar* always pays something below the rate of the best wet soil; generally speaking about a fourth less. On the whole it is regarded as an inferior soil, and the reason no doubt is that it always lies in depressions and is liable to damage from excess of water. The reason why the dry *dakar* rate is high in proportion is no doubt that under normal circumstances it can produce valuable crops without water. The most distinctive crops grown in *dakar* are rice and gram and, although no doubt in years of deficient rain-fall the rice will fail without irrigation, yet in an ordinary year it is probable that it gets as much water as it requires. Irrigation in the case of gram is of course exceptional.

5. I have looked up the old Settlement Report, but cannot find the soil map you refer to. I do not know that it would be of much assistance. There are, of course, tracts of extraordinarily uniform soil— witness the *parganas* of Baraut, Chaprauli and Katana, or at least as much of them as is not affected by the action of water on the ravines of rivers, but as a general rule the soil varies rapidly from village to village, and it is no uncommon thing to find one village containing all gradations of soil from the most incoherent sand to the very richest loam. I do not know who selected the samples of soil, but I think the selections might have been more typical. The richest part of the district, for instance, is undoubtedly the part of Baraut, Chaprauli and Katana to which I have referred; it has been called the richest tract in the North-West Provinces. There we have also, as I have said, a singularly uniform soil, and the analysis of a soil

sample taken from any part of the tract might fairly have been considered applicable to a larger area than in the case of a sample taken from any other part of the district, but I see that you have not had a single example from there. The only village, in fact, of which you have a sample from the whole of that *tahsil*, is Baghpat itself, and Baghpat being a village on the ravines of the Jumna, with rapidly varying soils, is, in my opinion, a very bad village from which to select a soil specimen.

STATEMENT No. X

Composition of Meerut Soils.

Laboratory No.	Description of Soil.	Village.	Pargana.	Total Nitrogen.	Total Phosphoric Acid.	Available Phosphoric Acid.	Available Potash.
[illegible]	Grey Clay . .	Loni . .	Loni . .	·064	·484	·340	·200
328	Ditto . .	Bagpat .	Bagpat .	·035	·131	·024	·020
323	Ditto . .	Sarsat Dargada	Barnawa .	·064	·310	·157	·061
304	Ditto . .	Jellalabad .	Jellalabad .	·055	·146	·066	·033
308	Ditto . .	Dhulana .	Dasna . .	·044	·204	·123	·068
313	Ditto . .	Sapuawat .	Ditto .	·070	·110	·039	·027
318	Ditto . .	Shah Mohayuddinpore .	Hapur . .	·076	·120	·045	·019
319	Ditto . .	Dastoi . .	Sarawa .	·035	·069	·016	·016
316	Ditto . .	Sapuawat .	Dasna . .	·053	·501	·432	·068
310	Ditto . .	Dhulana .	Ditto .	·051	·536	·411	·119
303	Grey Clay (Sotha)	Jellalabad .	Jellalabad .	·091	·544	·480	·125
296	Ditto . .	Loni . .	Loni . .	·038	·421	·209	·111
301	Grey Usar . .	Jellalabad .	Jellalabad .	·037	·110	·041	·015
299	Ditto . .	Dhulana .	Dasna . .	·068	·310	·230	·070
314	Yellow Usar .	Sapuawat .	Ditto .	·035	·061	·010	·014
298	Ditto . .	Loni . .	Loni . .	·021	·142	·047	·028
305	Yellow red loam	Sharf Dim Badar Chhawani .	Ditto .	·032	·151	·145	·013
307	Red loam . .	Ditto .	Ditto .	·037	·067	·015	·010
311	Yellow loam .	Ditto .	Ditto .	·038	·110	·044	·016
312	Ditto . .	Ditto .	Ditto .	·041	·241	·145	·035
324	Red loam . .	Bagpat .	Bagpat .	·041	·041	·032	·042
325	Ditto . .	Ditto .	Ditto .	·035	·061	·017	·007
321	Yellow loam .	Banoli .	Barnawa .	·048	·068	·015	·012
327	Red loam . .	Ditto .	Ditto .	·034	·080	·022	·016
302	Yellow loam .	Jellalabad .	Jellalabad .	·039	·096	·042	·042
315	Red loam . .	Sapuawat .	Dasna . .	·034	·065	·011	·005
326	Grey loam . .	Meerut .	Meerut . .	·037	·092	·055	·018
297	Red sandy . .	Sharf Din Badar Chhawani .	Loni . .	·023	·060	·031	·008
309	Yellow sandy .	Loni . .	Ditto .	·029	·068	·014	·012
330	Grey sandy .	Ranchhor .	Barnawa .	·034	·090	·062	·015
300	Red sandy . .	Jellalabad .	Jellalabad .	·034	·072	·043	·011
317	Yellow sandy .	Shah Mohayuddinpore .	Hapur . .	·020	·067	·027	·002
320	Red sandy . .	Dastoi . .	Sarawa . .	·025	·047	·005	·018
329	Yellow calcareous	Bagpat . .	Bagpat . .	·033	·104	·016	·014
322	Ditto . .	Prichhatgarh .	Khator . .	·046	·045	·003	·008

THE "CHOS" LANDS OF HOSHIARPUR DISTRICT.

46. At the end of 1894 I received samples of soil from three places in what are known as the Hoshiarpur *Chos* lands. These lands are the production of excessive deposits of sand, brought down by rivers from the Himalayas, on the top of the older agricultural soil of this part of India. The investigation was undertaken with a view to determine what difference there was between the newly-deposited sand and the older soil. Cause.

The following report, which was submitted in August 1895, contains the results of the investigation, to which is added a letter from the Deputy Commissioner on the subject of how long a time is required for the newly-deposited soil to become fertile :—

Report on the composition of six samples of soils from the "Chos" lands of the Hoshiarpur District, Punjab, which were forwarded by the Deputy Commissioner in November 1894 to the Agricultural Chemist to the Government of India.

The accompanying statement (No. XVII) exhibits the results of the chemicalanalyses which I have made of the above-mentioned soils. I have not yet had an opportunity of personally inspecting these lands, but I understand that they are subject to periodical floodings from the hill streams, and that it frequently happens that the silt left behind by the subsiding water is of a very sandy nature, so much so that good land is frequently covered with al oose sandy soil, the latter being agriculturally inferior to the older soil.

I suggested that samples should be sent to me from different spots, of which one (in each case) should be a sample of the newly-deposited soil, or what is now the "surface" soil, the other should be a sample of the older soil, which had become covered up, and which is now the sub-soil. Method of Sampling.

Three such pairs of samples were sent to me by the Deputy Commissioner of Hoshiarpur, in November 1894, which bore the labels "Hoshiarpur," "Dosuya", and "Garshankar," respectively, but I have not been informed at what depth the "sub-soil" samples were taken. I presume, however, that these latter were not at any great depth, but are found at some 12 to 24 inches below the surface. Sources.

Considering in the first place the mechanical condition of these

soils, the soil from Hoshiarpur and Dosuya were distinctly different from those from Garshankar.

Physical appearances.

The soil from Hoshiarpur was a light grey coarse sand at the surface, its sub-soil being somewhat darker, much finer, but still sandy The soil from Dosuya was a light grey course sand at the surface whilst its sub-soil was of a red colour, much finer, but still sandy. The surface soil from Garshankar was sandy, but reddish brown and much finer than the surface soll at Hoshiarpur and Dosuya, its sub-soil was very similar to it. Thus it seems that there is a similarity between the soils at Hoshiarpur and Dosuya which are, especially at the surface, much coarser sandy soils than that at Garshankar. In the statement of analyses, the pairs follow one another. Column 2 contains the result of analysis of the surface soil at Hoshiarpur; Column 3 those of its sub-soil; Column 4 those of surface soil from Dosuya; Column 5 those of its sub-soil; Column 6 those of surface soil from Garshankar; Column 7 those of its sub-soil.

Method of comparison.

In considering in what manner chemical analysis would best throw light on the respective merits of these soils, I decided to determine in each case the proportion of phosphoric acid and of potash which is readily or immediately available to plant life, and also in each case the *total* amount of phosphoric acid and of potash contained in them. I have also determined the amount of potash which is soluble in hydrochloric acid. This, like the proportion of "available" potash, indicates the relative extent to which these soils have decomposed.

The former determinations would thus show the relative *present* value of the soils, the latter would indicate whether the newly-deposited surface soil might eventually become as good as the older soil, if it should be inferior at the present time.

I have also determined the amount of nitrogen in these soils. There is at present no means of determining what proportion of the nitrogen in a soil is "readily available" to plants, and the figures in the statements all refer to the total amount of this constituent.

Nitrogen.

The further study of the figures in the statement is now simple In the case of the nitrogen, it will be seen that in each case the surface soil contains very much less nitrogen than its sub-soil, and, moreover, that the soils at Hoshiarpur and at Dosuya contain very much less nitrogen than that at Garshankar. The proportion of

phosphoric acid is not quite so regular. At Hoshiarpur the surface soil contains approximately as much of this constituent, whether readily available or not, as its sub-soil. In the Dosuya samples whilst the total amount of phosphoric acid is somewhat less in the surface soil than in the sub-soil, the amount readily available is much more. In the samples from Garshankar we find considerably less phosphoric acid, both "readily available" and total in the surface than in the sub-soil. In the case of the potash, however, we meet with greater uniformity. The proportion immediately available is much less in the surface soils at Hoshiarpur and at Garshankar than their respective sub-soil; the respective proportions in the Dosuya samples are equal and at the same time very small. The proportions of potash "soluble in hydrochloric acid," which includes much more than what is immediately available to plants, are in each of the three cases much less in the surface soils than in their respective sub-soils. Lastly, the proportion of total potash, though they vary somewhat among the samples, appears to be much about the same. The sub-soil at Dosnya contains less than the others, but this may be accidental.

Phosphoric acid.

Potash.

In conclusion, it would appear generally that the surface soils are agriculturally distinctly poorer than the sub-soils, at present, but that they will eventually become as good. They are, in two cases especially, very much coarser, and this means that they would dry very rapidly indeed, for they will not prevent water from passing downwards, and it will also evaporate much more quickly from their surface. The proportion of nitrogen is as usual in Indian soils, very low indeed, but it is not lower than I should have expected.

Top soil poorer than sub-soil.

The total amount of phosphoric acid is not high, but it appears to be generally in a readily available form.

The total amount of potash lastly is distinctly high, as is also that portion of it which is soluble in hydrochloric acid. The portion immediately available is in all cases fully ample for the requirements of average crops of cereals. The most important question in relation to these soils is "at what rate do they disintegrate and decompose"; *i.e.*, how soon may these new deposits be expected to become agriculturally equal to their sub-soils? If any information can be gained on this point, it would be most valuable.

Copy of a letter No. 145, dated 22nd May 1896, from Captain E. Inglis, Deputy Commissioner, Hoshiarpur.

Length of time required for new-soil to become food.

With reference to your office endorsement No. 2446, dated 14th September 1895, on Dr. Leather's Report on analysis of soils of Hoshiarpur *Chos*, I have the honour to report that a cultivated area, converted by *Chos* into pure sand, if properly planted with *kharkana* and manured with cow-dung, becomes fit for cultivation within 8 or 10 years, as observed in villages Naloian, Mazian and Dual. But as regards resuming its original fertility it takes much longer. This period is estimated not less than 50 years.

STATEMENT No. XVII.

Analysis of Samples of Soils from the Hoshiarpur District, Punjab.

	HOSHIARPUR.		DOSUYA.		GARSHANKAR.	
	(401) Surface soil.	(402) Sub-soil.	(403) Surface soil.	(404) Sub-soil.	(405) Surface soil.	(406). Sub-soil.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Nitrogen . .	·0065	·015	·0065	·023	·031	·067
Equal to Ammonia	·0078	·018	·0078	·027	·037	·081
Phosphoric acid available.	·015	·018	·021	·004	·038	·136
Phosphoric acid total.	·080	·073	·036	·049	·069	·261
Potash available.	·0092	·0215	·0069	·0065	·0499	·166
" soluble in Hydrochloric acid.	·137	·461	·156	·336	·412	·979
Potash total .	2·230	2·809	2·917	1·845	2·422	2·529

THE EXHAUSTION OF INDIAN SOILS.

47. The question whether the soil of India generally is becoming exhausted has been raised and discussed by more than one person, and is the somewhat natural outcome of the fact, which is at once brought to the notice of any one who visits India, namely, that a large part of the cattle manure is used as fuel. Clearly on the face of it, if "exhaustion" be taking place, it is a slow process, and strictly speaking one could only determine the matter by very careful observation and experiment carried on for a long period. It will be equally clear that it would have been impossible for me in the few years at my disposal to attempt such a series of experiments.

At the same time since I have had an opportunity of spending several years in India, it will not be out of place if I set out very briefly the views on the subject which I have come to hold, views I may observe which are in most respects in accord with those expressed by Dr. Voelcker, but to which I shall add something.

48. In the first place it will be well to refer for a moment to the opinion which Professor Wallace of Edinburgh (who spent 4 months in India in 1885 or 1886) expressed in his book entitled "*Indian Agriculture.*" He says (chapter 13, page 158) "One very important question with regard to India still continues to be asked: Is the fertility of the soil being exhausted by the native practices that have been going on for thousands of years? My unqualified answer is "No." He then proceeds to explain what he refers to under the term "soil," and describes in detail the process of surface washing which occurs annually throughout India. He concludes the paragraph with the words "By cropping in the ordinary way the native fertility of a soil cannot be lowered." The following paragraph, however, makes an all important explanation of what Professor Wallace means by "native fertility." "Temporary fertility the qualities possessed in virtue of some accumulation of material useful to plants, may be dissipated, but when this is gone no system of cropping can reduce the land to a lower point. The greater portion of the land in India, which is not newly broken in, annually produces its minimum yield. Where declining fertility has been recorded, it was no doubt due to loss of temporary fertility which had accumulated during a period of rest." This second paragraph then contains the all important admission that although the fertility of Indian soil is not being exhausted, still it can become more fertile by rest, and that formerly it contained a store of *temporary* fertility which has now gone, and that the land has reached a certain level below which it cannot descend.

Professor Wallace's opinion.

Fertility not being exhausted.

Temporary fertility.

I may here observe with regard to the distinction which Professor Wallace makes between *temporary* and the *natural* fertility of soils, that it is one which no other authority on agricultural subjects (so far as I am aware) has expressed, and it is clearly only a question of *terms*. The *natural* fertility of a soil, which Professor Wallace says cannot be destroyed, certainly includes more than the mere rocky particles of which a soil is composed, for some organic matter is certainly

Impossible to define temporary fertility

also a component part, and how one is to distinguish between this portion of organic matter belonging to the *natural* fertility, and that other portion of organic matter which belongs to Professor Wallace's *temporary* fertility, is a problem which it is quite impossible to solve, since they both are the product of the decay of plants or parts of plants in the soil. The presence of a store of "temporary" fertility in the past *may* or may not be the case; the opinion that a soil cannot be reduced in fertility below a certain level is one for which there is absolutely *no* proof; on the other hand, we have the *fact* that in the Rothamsted and Woburn Experimental Fields in England the crops which have been grown for so many years without the aid of manure do annually become less and less, and the limit (if there be one) has not so far been reached.

Nitrogen in Rainfall.

49. This fact is pointed out by Dr. Voelcker, and he further examines three questions which have a close relation to the main one. The first is "How much nitrogen is added to the soil by rain." The rainfall at Rothamsted brings annually about 4·5 ℔ of nitrogen to the land. For some time it was contended that the rain in India brought very much more than this, and figures, which were afterwards proved erroneous, were quoted in support of the fact. Later determinations by Dr. Van Geyzel of Madras showed in 1888 4 ℔ and in 1889 only 2·1 ℔ per acre of nitrogen to have been so deposited; later in 1891 Mr. Bamber, then Chemist to the Indian Tea Association, Calcutta, found that the nitrogen in the rain-fall from May to October was equal to 3·4 ℔ ammonia. Thus then it is practically certain that no large amount of this all-important plant food is added to the soil from this source.

(Margin notes: **Rothamsted.** **Madras.** **Calcutta.**)

Effect of growing pulses.

The second point which bears upon the question is "What is the effect of growing such large quantities of pulses and other leguminous plants in India? What amount of nitrogen is supplied indirectly by this means to other crops?" Unfortunately, there is no answer to this question at present. All that one can say is that, knowing as we do that the members of this natural order *do* assimilate atmospheric nitrogen, they are a means of adding this plant-food to the soil, and doubtless it forms a very important item in relation to Indian agriculture.

Effect of exporting grain.

50. The third point which has been brought into the discussion is the effect of the export of grain, oil-seeds and bones from India

Dr. Voelcker considers, as others have done, that this forms a serious loss. He says (para. 51) "On the one hand there is a large export of oil-seeds, cotton and other products besides an increasing one of wheat, all of which remove a considerable amount of the soil constituent. What is returned in their place? Only the straw or the stalks and leaves; and it is not even correct to say that these are returned, for, after all, it is only a portion, and frequently a very small portion, that does find its way back to the soil. Part is necessarily used up in the bodies of the cattle, part is wasted by imperfect conserving and storing of manure, part must unavoidably be lost, however great the care that may be taken; thus it comes about that it is only a fraction that contributes finally to making up the loss the soil has sustained. Were, on the contrary, all grain to be consumed by the people, and all night-soil to be used in agriculture; were all refuse of oil-seeds (after pressing out the oil) to be utilised for manure; were all straw to be consumed by cattle, and the droppings, solid and liquid together, to be carefully preserved; lastly, were all stalks and leaves to be buried again in the land, then the balance might be more nearly preserved. But, as things are, the exports of oil-seeds, grain, etc. (that of bones I will discuss later), simply mean so much of the soil constituents carried off, for which no adequate recompense is made.

Effect of export probably over-rated.

To my mind this matter of export of agricultural produce has been gauged as far more serious than a consideration of the facts of the case will allow. In the paragraph just quoted from Dr. Voelcker's Report he says that if the residual matters of the crops produced in India were returned to the soil, the balance would be maintained, and it is clear that one may take this to be a fundamental fact. But it is also clear that export of agricultural produce out of India can only become a serious item *when it removes a material proportion of the plant-food which is extracted by each crop*. Now what is this proportion? In a paper entitled "*Memorandum on the Resources of British India*," Dr. Watt makes an estimate of 5,72,15,000 tons as the production of food grain, which however Dr. Watt does not consider very accurate. I myself think it may be somewhat too high. Nevertheless, it is not so utterly wrong as to be worthless for the purpose in question. The total exports of food grains is, about 25,00,000 tons, or roughly 5 per cent. of the production, and accordingly some 5 per cent. of the plant-food which the grain of the crops annually extracts

Reasons.

from the land is exported. Now what is the amount of plant-food which grain crops in India take up to form their substance? If we allow it to be some 15 lb. of nitrogen and half that amount of phosphoric acid per acre (which are the only items that need be taken into account) such an estimate cannot be considered too low; indeed it is in all probability too high. This is the amount, moreover, which is taken up by the whole crop (straw included). Since only grain is exported, it follows that it is not 5 per cent. of the abovenamed quantity, but 5 per cent. to a still smaller figure (probably [illegible] or [illegible] of it) which would represent the drain of these plant-foods per acre caused by export, or in other words it will not be much more than half a pound of nitrogen and quarter of a pound of phosphoric acid per acre per annum, and may be it is less than this! Such quantities as these are in all probability amply replaced by nature.

A similar result is obtained if one calculates, from the known amounts of nitrogen and phosphoric acid in the exported grain, the amount of these substances per acre. But by deducing the figures in the manner adopted, it is more clearly brought out how small a proportion of materials, required for the grain crops of India, are thus taken out of the country.

Loss made up for by natural means.

It has already been mentioned that the rainfall brings down annually several pounds of nitrogen per acre and this agency alone much more than makes up for the loss of this element caused by export. And in the case of the phosphoric acid, the annual movement of silt from higher to lower ground on to the land by the monsoon rainfall must be admitted to be a source of mineral plant-food.

Thus there can hardly be any doubt that the export of food grain from India has been considered to be a far more serious drain than it really is.

Export of bones.

And similarly in the case of bones, quite apart from the fact that at only one of the five experimental farms has this material been found of any value as manure, if the amount of phosphate exported be referred to the acreage, it will be at once evident how utterly impossible it is that this trade can be exercising any influence on the fertility of the land.

51. To my mind it is much more important to consider how the fertility of the land can be increased, than to consider whether the land is becoming exhausted. "Exhaustion" is a purely relative term; it is highly improbable that in any process of agriculture a certain level is finally reached below which fertility cannot descend, and it

would be much more correct to say the fertility of the land in India is not only low compared with that of other countries, but that if it is not *decreasing*, it is certainly not *increasing*. It must also be admitted that with a better supply of manure fertility would be *immediately* increased and more grain produced per acre. And for that better supply of manure there is only one principal source, namely, the dejecta of the human beings and animals that consume very nearly the whole of the grain crops, straw included.

Fertility would be increased by manuring.

It is in the more perfect direct (not indirect) return to the land of these matters that one can look for an increased manure supply, an increased fertility, an increased outturn of food grain. Doubtless under present circumstances there are many difficulties to be overcome before anything like great economy will be realised in this direction. There is the scarcity of fuel which occasions the loss of nitrogen and organic matter of a very large proportion of the dung of agricultural animals; there is doubtless a great deal of carelessness among cultivators (more in some parts than in others) as to the preservation of such refuse materials as are not burnt; there is a similar want of method practised in relation to the night-soil. These difficulties may some day be removed. In the meantime they *must* remain an acknowledged fact, and that but for these obstacles the land *would* be more productive than it is. Further, so far as nitrogen is concerned, it may be kept in mind, that of the other two sources of this element, the rain is annually giving several pounds per acre, and that the LEGUMINOSÆ are also beneficial in a like direction. But to what extent they are thus beneficial is a problem which remains for future investigators to determine.

Importance of direct return to the land of animal faeces.

S. 2260 a.

G. I. C. P. O.—No. 499 R. & A.—20-6-98.—2,200.—H. R

All communications regarding THE AGRICULTURAL LEDGER should addressed to the Editor, Dr. George Watt, Reporter on Economic roducts to the Government of India, Calcutta.

The objects of this publication (as already stated) are to gradually evelop and perfect our knowledge of Indian Agricultural and Economic uestions. Contributions or corrections and additions will therefore be ost welcome.

In order to preserve a necessary relation to the various Departments Government, contributions will be classified and numbered under certain ries.* Thus, for example, papers on Veterinary subjects will be regised under the Veterinary Series; those on Forestry in the Forest Series. apers of more direct Agricultural or Industrial interest will be grouped cording as the products dealt with belong to the Vegetable or Animal ngdom. In a like manner, contributions on Mineral and Metallic subts will be registered under the Mineral Series.

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* This sheet and the title-page may be removed when the subject-matter is filed in its proper place, rding to the letter and number shown at the bottom of each page.

NOTICE.

Future issues of this publication placed under either the "Special Veterinary" or "Special Forest Series" will not be included in the annual enumeration. Such papers are printed for Departmental purposes. Their unfortunate inclusion in the system of annual numbering has led recipients of the ordinary issues to think their sets incomplete.

The following pamphlets have already appeared as Special issues, and have not accordingly been furnished to the public:—

1894 . .	Nos. 8, 9, 10, 11, 13 and 15.
1896 . .	No. 8.